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THE FOSSIL FLORAS OF KACHCHH. III — TERTIARY MEGAFOSSILS

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ABSTRACT

A complete account of plant megafossils described so far from the Eocene, Miocene and Pliocene beds of Kachchh District has been given. The megafossils belong to Algae and Phanerogams. The algal remains comprise the calcareous red algae assigned to the family Corallinaceae. Out of eight species belonging to five genera, three species representing the two genera: *Lithothamnium* and *Lithophyllum*, have been reported from the Eocene and five species belonging to the genera *Lithophyllum*, *Mesophyllum*, *Archaeoporolithon* and *Aethesolithon* are from the Lower Miocene deposits. The phanerogamous megafossils have been described from the Lower Eocene, Miocene and Pliocene beds. The Eocene megafossils consist of leaf-impressions belonging to eight species of dicotyledons and one species of monocotyledons. The Miocene assemblage is based on leaf-impressions, seeds and petrified woods assigned to 14 genera and 15 species of dicotyledons and a palm. The megafossils recovered from the Pliocene deposits are all petrified woods belonging to seven families (5 dicotyledons, 1 palm and 1 gymnosperm) represented by 14 genera. Besides, two palm woods and a graminaceous stem reported from unknown Tertiary horizons have also been included.

In the light of distribution of their modern comparable forms, all the components of the Tertiary flora of Kachchh are tropical. Because of the occurrence of moist evergreen as well as deciduous taxa, the flora can be placed under the category of "moist tropical semi-evergreen to deciduous forests". The environment of deposition seems to have been mainly lacustrine and fluviatile. The overall vegetation of Kachchh during the Tertiary period was more luxuriant than the scrubby vegetation thriving there today. Obviously the present xeric conditions are a result of post-Pliocene changes in the climate in this area. Even during the Tertiary, Kachchh witnessed periodic changes in climate. It was moist during the early Eocene, gradually becoming comparatively drier during early Miocene and again turning moist towards the end of Miocene.

The occurrence of marine algae in the Eocene and Miocene deposits indicates that there was transgression of sea in Kachchh during Eocene and Miocene epochs.

Key-words — Megafossils, Algae, Woods, Leaves, Fruits, Tertiary, Kachchh (India).

सारांश

कच्छ के अश्मित वनस्पतिजात. 3 — तृतीयक युगीन गुरुपादपाश्म — राजेन्द्रनाथ लखनपाल, जसवन्त सिंह गुलेरिया एवं नीलाम्बर अवस्थी

कच्छ जनपद के आदिनूतन, मध्यनूतन एवं अतिनूतन कालीन संस्तरों से अभी तक वर्णित गुरुपादपाश्मों का पूर्ण विवरण दिया गया है। ये गुरुपादपाश्म शैवालों एवं पुष्पोद्भिदों से सम्बद्ध हैं। शैवालीय अवशेष कोरेलाइनेसी कुल से सम्बद्ध चूनामय लाल शैवालों के हैं। पाँच वंशों की आठ जातियों में से तीन जातियाँ जो लिथोथैमनियम् एवं लिथोफ़िल्लम् नामक वंशों का निरूपण करती हैं आदिनूतन युग से अभिलिखित की गई हैं तथा शेष पाँच जातियाँ अधरि मध्यनूतन निक्षेपों से वर्णित की गई हैं, ये जातियाँ लिथोफ़िल्लम्, मीसोफ़िल्लम्, आर्कियोपोरोलिथॉन एवं ऐथिसोलिथॉन नामक वंशों से सम्बद्ध हैं। पुष्पोद्भिदी गुरुपादपाश्म आदिनूतन, मध्यनूतन एवं अतिनूतन युग से वर्णित किये गये हैं। आदिनूतन कालीन गुरुपादपाश्मों में एकबीजपत्रीयों की एक जाति के तथा द्विबीजपत्रीयों की आठ जातियों के पर्ण-छापाश्म हैं। मध्यनूतन समुच्चय पर्ण-छापाश्मों, बीजाश्मों, द्विबीजपत्रीयों के 14 वंशों से सम्बद्ध 15 जातियों तथा ताड़ की एक जाति की अश्मीभूत काष्ठ पर आधारित है। अतिनूतन निक्षेपों से उपलब्ध सभी गुरुपादपाश्म सात कुलों का निरूपण करने वाले 14 वंशों (पाँच द्विबीजपत्री, एक ताड़ एवं एक अनावृतबीजी) की अश्मीभूत काष्ठों के हैं। इसके अतिरिक्त अज्ञात तृतीयक संस्तरों से अभिलिखित दो ताड़-काष्ठ एवं ग्रेमिनी कुल का एक स्तम्भ भी इस शोध-पत्र में सम्मिलित किये गये हैं।

वर्तमान तुलनीय प्रारूपों के वितरण के अनुसार कच्छ के तृतीयक युगीन वनस्पतिजात के सभी अवयव उष्णकटिबंधीय हैं। आर्द्र सदाहरित एवं पर्णपातों वर्गकों की उपस्थिति के फलस्वरूप उपलब्ध वनस्पतिजात को "आर्द्र उष्णकटिबंधीय अर्ध-सदाहरित से पर्णपाती वनों" की श्रेणी में रखा जा सकता है। निक्षेपण का वातावरण मुख्यतया सरोवरी एवं नदीय प्रतीत होता है। तृतीयक युग में कच्छ की सम्मिलित वनस्पति वर्तमान झाड़ीदार वनस्पति की अपेक्षाकृत अत्यन्त समृद्ध थी। अतएव यह स्पष्ट है कि इस क्षेत्र में वर्तमान शुष्क परिस्थितियाँ अन्तिम-अतिनूतन काल में हुए जलवायु में परिवर्तनों के फलस्वरूप ही हैं। यहाँ तक कि तृतीयक युग में कच्छ से जलवायु में कालिक परिवर्तनों के प्रमाण मिले हैं। प्रारम्भिक आदिनूतन काल में यहाँ नम जलवायु थी जो प्रारम्भिक मध्यनूतन काल में शनैः शनैः अपेक्षाकृत शुष्कतर होती चली गई तथा मध्यनूतन काल के अन्तिम चरण में पुनः आर्द्र हो गई।

आदिनूतन एवं मध्यनूतन कालीन निक्षेपों में समुद्री शैवालों की उपस्थिति से यह इंगित होता है कि आदिनूतन एवं मध्यनूतन काल में कच्छ में समुद्र का अतिक्रमण था।

INTRODUCTION

AREA and climate — The *Kachchh District forming the north-western part of the Gujarat State, lies between Lat. 22°44′-24°42′ N and Long. 68°08′-71°46′ E (see Map 1). The total area of the district is 45,652 sq km. It consists mainly of flat dry land with a few ranges of scattered naked hills and isolated hillocks besides valleys, rivers, nalas and tracts of pasture land.

The hill ranges, running east west, do not exceed 300 metres in height and consequently are not capable of supporting a permanent river system. Lying north beyond the course of south-west monsoon, it falls in the zone of scanty rainfall and for the greater part of the year the climate in Kachchh remains dry. The average annual rainfall is about 35 cm, ranging between the maximum of 88 cm and the minimum of 5.0 cm, of which about 90 per cent precipitates between June and September. The annual average temperature varies between 20°C and 33°C (Climatological Tables of Observatories in India, 1931-1960).

Present vegetation — As a result of dry climate the flora of Kachchh has predominantly xerophytic character. According to Rao (1970, pp. 125, 133) the flora consists of about 700 species distributed amongst 95 families and 367 genera. The eleven dominant families are Poaceae (81 species), Leguminosae (76 species), Asteraceae (35 species), Malvaceae (32 species), Convolvulaceae, Euphorbiaceae and Cyperaceae (25 species each), Acanthaceae (21 species), Amaranthaceae (19 species), Cucurbitaceae (18 species) and Boraginaceae (17 species). The plants of this area and a comprehensive bibliography about them have been given by Shah (1978) in his "Flora of Gujarat State". Recently some more plants from this area have been recorded by Rao and Sabnis (1983).

Phytogeographically Kachchh is very significant as it is the meeting ground for the arid African and Arabian elements with those of India (Bharucha & Meher-Homji, 1965; Chatterjee, 1940, 1962; Puri, 1960; Legris, 1963; Mahabale, 1966). The flora of Kachchh shows resemblance with that of Sind as well as of Gujarat, though the affinities with the former are more pronounced. Blatter (1909) has pointed out that out of 345 species, about 200 are common with those of Sind and 160 with those of Gujarat. It is interesting to observe that more and more plants reported from Sind are now being found in Kachchh and many of them do not extend east of Kachchh. The thorny scrub jungle forms the dominant vegetation of Kachchh. It is composed of *Acacia leucophloea* Willd., *A. nilotica* (L) Willd. ex Del. subsp. *indica* (Benth.) Brenan (syn. *A. arabica* Willd.), *A. senegal* Willd., *Balanites aegyptica* Delile., *Calotropis gigantea* R.Br., *Capparis decidus* Edgew., *C. grandis* L.f., *Cassia auriculata* Linn., *Clerodendrum multiflorum* (Buran. f.), Ktze., *Commiphora wightii* (Arn.) Bhandari, *Euphorbia neriifolia* Linn., *E. nivulia* Buch-Ham, *E. tirucalli* Linn., *Grewia flavescens* Juss., *G. tenax* Fiori, *G. villosa* Willd., *Indigofera* spp., *Mimosa hamata* Willd., *Periploca aphylla* Decane., *Premna resinosa* Schau., *Prosopis cineraria* (L.) Macbr., *P. chilensis* (Molina) Stuntze, *Ziziphus mauritiana* Lam., *Z. nummularia* (Buran. f.) W. & A.

In the protected and moister situations, such as valleys of the hills at Dhinodhar, Kala Dungar and Motadhola, the vegetation

*In the earlier literature spelt as Cutch or Kutch.

tends to develop into good deciduous tracts which resemble the typical dry deciduous forests of Deccan Traps, with such species as *Bauhinia racemosa* Lam., *Bombax ceiba* Linn., *Cordia dichotoma* Forst. f., *C. myxa* Linn., *C. rothii* Roem. & Schult., *Ehretia laevis* Roxb., *Ficus* sp., *Gymnosporia montana* Benth., *Lannea coromandelica* Merr., *Lawsonia inermis* Linn., *Moringa oleifera* Lam., *Odina wodier* Roxb., *Phoenix sylvestris* Roxb., *Prosopis specigera* Linn., *Sterculia urens* Roxb., and *Vitis trifolia* Linn.

Rocky habitat with poor shallow soil and waste lands, is colonized by abundant growth of *Cassia* spp. and *Butea monosperma* Ktze. Dense colonies of *Echinops echinatus* Roxb. occur in freshly exposed hard rocky soils along the railway lines. The climbers in the area are few, such as *Abrus precatorius* Linn., *Cardiospermum halicacabum* Linn., *Cissus quadrangularis* Linn., *Clitoria ternatea* Linn., *Cocculus hirsutus* Diels., *C. pendulus* Diels., *Daemia extensa* R.Br., *Ipomoea pilosa* Sweet and *Tragia* sp. The saline tracts and the riverain areas have sparse scrub forests of *Calotropis procera* R.Br., *Salvadora oleoides* Decne., *S. persica* Wall., and *Tamarix* spp.

There is paucity of aquatic plants because there are very few fresh water habitats. *Typha angustata* Bory & Chaub. is the conspicuous plant in the marshy areas. Mangroves occur all along the coast, mostly poor and disturbed. *Avicennia alba* Bl. is the commonest mangrove plant. The other mangrove trees are *Aegiceras corniculatum* Blanco., *Avicennia officinalis* Linn., *Bruguiera conjugata* Merr., *Ceriops candolleana* Arn., *Rhizophora candelaria* DC. and *R. mucronata* Lam. The scrubs and prostrate herbs include *Cressa cretica* Linn., *Haloxylon recurvum* Bunge., *Juncus maritimus* Lam., *Salicornis brachiata* Miq., *Salsola foetida* Del., *S. fruticosa* Linn., *Suaeda nudiflora* Moq. and *Urochondra setulosa* (Trin) Hubb. The sandy banks along sea-creeks have dense growth of *Aelurophus lagopoides* (L.) Tirn ex. Thwaites, *Asparagus dumosus* Baker, *Atriplex* sp., *Crotalaria burhia* Ham. and several grasses. Some epiphytes and ground parasitic plants also grow in the area.

Geology and plant fossil localities — In Kachchh the Tertiary sediments are represented by a complete sequence from Palaeocene to Pliocene (see Map 1), which is best developed in south-western Kachchh, attaining a thickness of about 650 m (Biswas & Raju, 1973). These sediments were deposited on the eroded surface of Deccan Trap flows and the Mesozoic sedimentary rocks. The stratigraphical classification followed herein is basically the same as given by Biswas and Raju (1973) and briefly outlined in Table 1.

Tertiary plant megafossils have been collected from the following localities (shown in Map 1), which are easily accessible either by metalled or *Kutcha* motorable roads.

(A) *Algal localities*:

(i) *Babia Hill* — The Babia hill (23°42′30″ N; 68°47′ E) is about 122 km NW of Bhuj and is situated about 5 km NE of the village Panandhro. Eocene algae have been reported from this place.

(ii) *Waior* — The village Waior is about 15 km east of Goyela and about 25 km NE of Naliya. Rock samples containing algae have been reported from the eastern side (23°25′ N: 68°41′ E) of the village.

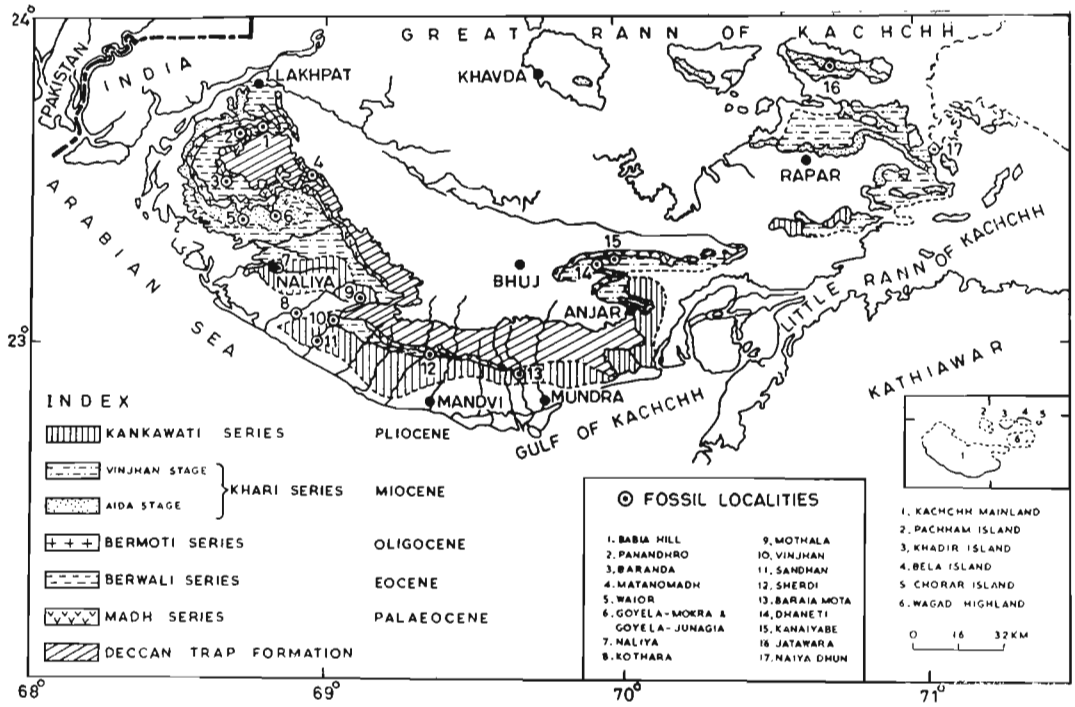
(B) *Leaf-impression localities*:

(i) *Panandhro* — The village Panandhro lies on the Bhuj-Narayan Sarovar Road and is 126 km NW of Bhuj. Leaf-impressions are found in abundance in the Eocene deposits of Panandhro Lignite Mine (23°41′45″ N; 68°47′22″ E) which is about 2.0 km east of the village.

(ii) *Matanomadh* — The village Matanomadh (23°32′30″ N; 68°57′10″ E) is about 93 km NW of Bhuj on the Bhuj-Lakhpat Road. Highly fragile leaf-impressions are found in tuffaceous sediments of Madh Series (Palaeocene) around the village. Leaf impressions are also seen in the Eocene exposures around Matanomadh.

(iii) *Baranda* — This village (23°34′20″ N; 68°43′10″ E) is about 18 km NNW of Waior and about 35 km south of Lakhpat. Leaf-impressions of Middle Eocene age have been found about 2 km SSE of the village in the rocks exposed in the Ratchelo Nala Section.

(iv) *Sherdi/Serdi* — The village Sherdi/Serdi (23°0′44″ N; 69°20′15″ E) lies 42 km SW of Bhuj. The river Kharod flows near the village and the fragmentary leaf-impressions belonging to Eocene have been collected from near a massive section exposed along the river bank about 2 km from the main road (Bhuj-Mandvi Road).



MAP 1

(v) *Goyela-Mokra (Khari Nadi Bed)* — The twin villages, Goyela and Mokra, are situated west of Bhuj or north of Naliya. The fossil locality (23°25′20″ N; 68°52′ E) lies about 2.5 km south of Goyela-Mokra on the southern bank of the Khari Nadi, about 100 m east of road where it cuts the river bed. Impressions of leaves, fruits and seeds are found in the sediments of Khari Series (Lower Miocene) of this locality.

(vi) *Goyela-Junagia* — A few fragmentary leaf-impressions have been collected about 1 km north of the village Goyela on Goyela-Junagia camel cart tract. The leaf-impressions occur in a weathering mound on the right side of the path while moving from Goyela to Junagia where the sections are exposed. The impressions are of Lower Miocene age.

(vii) *Jatawara* — The village Jatawara (23°49′46″ N; 70°42′45″ E) is about 29 km north of Rapar in the Bela Island. Fragmentary leaf-impressions of Lower Miocene age are found in white sandy band (sandy shale) on left side of the mouth of dam on a river.

(C) *Wood localities*:

(i) *Naliya* — It is one of the important towns of Kachchh and is situated SW of Bhuj. Wood samples were collected from the Naliya-Mandvi Road where there is a diversion for Jakho Port. The woods were found scattered or buried in a small nala and water cuttings and gullies on the left side of the road as one moves from Naliya to Mandvi. The woods seem to belong to Kankawati Series (Pliocene).

(ii) *Kothara* — This is a fairly big village and is situated south-east of Naliya. Some small wood pieces were collected very close to the village at about 17 km from Naliya in the bed of Naira River, where the road cuts the river. The woods most probably belong to Pliocene.

(iii) *Mothala* — This village is about 58 km WWS of Bhuj, on the Bhuj-Naliya road. The woods are strewn or buried in an extensive area towards south of the village (23°8′ to 23°10′ N; 69°10′ to 69°12′E) up to Kankawati River. Most of the woods were found in the *Acacia* thicket between the

small cemented canal and the *Kutcha* road going to Soda Camp as one approaches this area from the main road (Bhuj-Naliya Road) near a small bridge on a culvert, before taking a turn to Mothala village. Fossil logs over 3 metres long were observed in the field. The woods belong to the Kankawati Series (Pliocene).

(iv) *Vinjhan* — The village Vinjhan is about 16 km SW of Mothala (23°6′8″ N; 69°1′30″ E). The fossils were collected from the bed of Kankawati River (SSE of the village) which flows south of the village.

(v) *Sandhan* — This village is situated on the west bank of Kankawati River, about 11 km south of Vinjhan (23°1′12″ N; 68°59′ 38″ E). The fossil woods were collected from the river bed.

The fossils collected from Vinjhan and Sandhan are similar to those collected from Mothala which is situated about 16-27 km north (upstream) of these two villages. In all likelihood fossil woods have been brought down here by Kankawati River from Mothala where much bigger logs have been found. Thus the woods of these two localities are also of Pliocene age.

(vi) *Baraia Mota* — The village Baraia Mota lies (22°55′ N; 69°41′ E) on the bank of Phot River, 42 km south of Bhuj on the Bhuj-Mundra Road. One piece of a gymnospermous wood was recovered about 2 km upstream, where the road passes through the river in the gullies formed by the rain water channels, which ultimately merge into the Phot River.

(vii) *Dhaneti* — This village is situated about 24 km east of Bhuj, on the Bhuj-Bhachau Road. Petrified woods are found strewn in a large area (25°16′2″ to 23°17′ 30″ N; 69°56′ to 69°58′30″ E) in the fields on both sides of the road. However, they are in abundance and bigger in size opposite the village across the road. The age of these woods is considered to be Pliocene.

(viii) *Kanaiyabe* — This village is about 33 km east of Bhuj, on the Bhuj-Bhachau Road. Woods similar to those collected from Dhaneti were found on both sides of the road from an area lying between 23°16′52″ to 23°17′30″ N; 70°1′33″ to 70°2′27″ E. These woods belong to Kankawati Series (Pliocene).

(ix) *Naiya Dhun* — It is a solitary hillock in the Little Rann of Kachchh (23°36′ N; 71°7′ E) between Piprala and Adesar. It is about 6 km SSW of Piprala and 11 km EEN of Adesar. A few fossil woods of Miocene age have been collected from this hillock.

Resumé of studies

The discovery of plant fossils in the Tertiary of Kachchh dates back to 1872 when Wynne reported fossil woods and leaves from these beds. However, our knowledge regarding the Tertiary megafossils of this area remained extremely poor until 1975 when we took up the detailed investigations, starting with the description of a gymnospermous wood from a Pliocene deposit (Lakhanpal *et al.*, 1975).

Before 1975, there were possibly five angiospermous and five algal fossils known from the Tertiary of Kachchh. Ghosh and Ghosh (1959) were the first to describe a dicot wood of *Dipterocarpoxylon malavii* from the Pliocene beds of Mothala. Prakash and Dayal (1968) reported a fossil wood of *Terminalia tomentosa* Wight & Arn. from near Ratnal Railway Station. In addition, two palm stems, *Palmoxylon mathuri* and *P. seriatum* were described by Sahni (1964) which were believed to have come from the Cretaceous of Kachchh. Sahni (1964) also reported the occurrence of cylinderical reed like stems, viz., *Culmites cutchensis*, belonging to the family Gramineae. The age of these three monocot fossils is doubtful. Extensive collections made by the Mesozoic workers in this area have not been able to find a single piece of fossil palm from any of the Cretaceous localities which otherwise abound in plant fossils. However, fossil palms have recently been reported from the Miocene and Pliocene beds of Kachchh by Lakhanpal and Guleria (1982), and Guleria (1983). This tends to indicate that the three monocots reported by Sahni most probably belong to Tertiary. The credit of recording the Tertiary algae goes to Pal and Ghosh who in 1974 reported the occurrence of *Lithophyllum*, *Mesophyllum*, *Aethesolithon* (2 spp.) and a new genus *Archaeoporolithon* from the Lower Miocene of south-western Kachchh.

After 1975, a number of leaf-impressions and fossil woods have been described by Awasthi *et al.* (1980, 1982); Guleria (1983, 1984); Guleria and Lakhanpal (1984) and Lakhanpal and Guleria (1981, 1982). The

TABLE 1 — CENOZOIC STRATIGRAPHY OF KACHCHH

Lithostratigraphic Units (Biswas & Deshpande (1970); Biswas & Raju (1971, 1973))			Time Stratigraphy Units (Biswas (1965, 1971) Biswas & Deshpande (1970))		Epoch or Age
Formation	Member	Lithology			
RECENT	—	Unconsolidated conglomerates, grits, kankars, silt, sand, alluvium, etc.	RECENT		RECENT
----UNCONFORMITY-------					
MILIOLITE	—	Pelletoidal calcareous sandstones sandy pelmicrites and oomicrites	PORBANDAR SERIES		PLEISTOCENE
-----UNCONFORMITY-------					
SANDHAN	—	Grey sandstones, pink fossiliferous calcareous grits and conglomerates with subordinate shales	KANKAWATI SERIES		?PLIOCENE
-----DISCONFORMITY-------					
VINJHAN	SILTSTONE	Micaceous-gypseous shales and laminated siltstones	KHARI SERIES	VINJHAN STAGE	MIOCENE — LANGHIAN
SHALE	CHHASRA	Clay with fossiliferous marls			MIOCENE — BURDIGALIAN
KHARI NADI	—	Red, yellow and variegated siltstones		AIDA STAGE	MIOCENE — AQUITANIAN
MANIYARA FORT	BER MOTI	Upper-foraminiferal limestones and marlite Lower-Argillaceous, glauconitic sandstones	BERMOTI SERIES	WAIOR STAGE	OLIGOCENE — CHATTIAN
	CORAL LIMESTONE	White, nodular foraminiferal limestones, glauconitic biomicrites and biosparites		RAMANIA STAGE	OLIGOCENE — RUPELIAN
	LUMPY CLAY	Lumpy clay stone with occasional limestone bands			
	BASAL	Glauconitic claystones and siltstones			OLIGOCENE — LATTORFIAN
-----PARACONFORMITY-----					
FULRA LIMESTONE	—	Foraminiferal limestones and marls (foraminiferal micrites, biomicrites and biomicrosparites)	BERWALI SERIES	BABIA STAGE	EOCENE — LUTETIAN
HARUDI	—	Upper-Calcareous claystones and gypseous shales with occasional carbonaceous shales. Lower-greenish grey shale with a conquina bed near the base			
-----DISCONFORMITY-------					
NAREDI	FERRUGINOUS CLAYSTONE	Claystones with layers of gypsum and grey ferruginous laminae		KAKDI STAGE	EOCENE — YPRESIAN
	ASSILINA LIMESTONE	Argillaceous limestones studded with *Assilina*			
	GYPSEOUS SHALE	Glauconitic claystones and gypseous shales with thin bands of calcareous concretion			
-----UNCONFORMITY-------					
MATANOMADH	—	Laterite, tuffaceous shales, sandstones and grits, bentonitic and ferruginous clay with volcanic ash	MADH SERIES		PALAEOCENE
DECCAN TRAP	—	Dark green, columnar and amygdaloidal, basaltic flows. Locally Intertrappean beds are present	DECCAN TRAP		UPPER CRETACEOUS TO ?LOWERMOST PALAEOCENE

mega-algae were further reported by Kar (1979) from the Middle Eocene sediments. The megafossils of bryophytes and pteridophytes have not been recovered so far.

The present work brings together the descriptions of all the hitherto known records of Tertiary megafossils. Besides, some new data have also been added. Till now petrified woods were known only from the Pliocene (Kankawati Series) beds. However, in the present work a few fossil woods from the Miocene beds have also been described.

Although megafossils are found in a large number of localities as reported in the earlier section, all of them have not been investigated so far. For instance the leaf impressions from Matanomadh are too fragile for study. Similarly the specimens collected from Sherdi, Junagia and Jatawara are fragmentary and not well-preserved.

GENERAL DESCRIPTION

EOCENE MEGAFOSSILS

ALGAE

Class — Rhodophyceae

Genus — *Lithothamnium* Philippi, 1837

Lithothamnium sp. cf. *L. validum* Foslie, 1895

Pl. 1, fig. 3

1979 *Lithothamnium* sp. cf. *L. validum*, Kar, p. 89, pl. 1, fig. 1

Description (from Kar, 1979) — Few thalli could be recovered, thalli entirely made up of perithallium. Perithallial cells squarish to rectangular measuring 7-9×8-11 μm. Longitudinal cells slightly thicker, continuous, transverse ones thinner, discontinuous. Conceptacles irregular in shape, often filled with irregular cellular tissue.

Figured Specimen — B.S.I.P. slide no. 5918/1.

Occurrence — Fulra Limestone (Middle Eocene) exposed at Babia Hill.

Comparison and discussion — The fossil shows close resemblance with *Lithothamnium validum* Foslie described by Johnson and Stewart (1953) from the Meganos Formation (Middle Eocene) of California, U.S.A. The occurrence of *Lithothamnium validum* has been reported by Taylor (1945) from Mexico and by Dawson (1960) from Galapagos islands. However, according to Johnson (1962) *L. validum* is absent in Pacific Ocean of Mexico.

Lithothamnium sp. cf. *L. bofilli* Lemoine, 1939

Pl. 1, fig. 1

1979 *Lithothamnium* sp. cf. *L. bofilli*, Kar, p. 83, pl. 1, fig. 2

Description (from Kar, 1979) — Hypothallium mostly absent in the specimens studied. Perithallial cells well-preserved, form a regular lattice with thicker horizontal and thinner vertical cells. Cells squarish to rectangular in shape, varies from 6-10×8-12 μm in size. Conceptacles while present, irregular, filled with cellular tissue.

Figured Specimen — B.S.I.P. slide no. 5919/1.

Occurrence — Fulra Limestone (Middle Eocene) exposed at Babia Hill.

Comparison and discussion — According to Rao (1943) *Lithothamnium bofilli* Lemoine is characterized by a thin thallus and its hypothallial cells are bigger than the perithallial cells. The species has been recorded from the Eocene of Spain, Algeria and Assam. The fossil could not be compared with the living species in detail due to lack of epithellial cells in it.

Lithothamnium is the most wide-spread genus of all the coralline algae. The genus is well-represented in Tertiary and specially very common in Eocene and Miocene. It's earliest record comes from Late Jurassic (Wray, 1977, p. 68). According to Rao (1943) the genus is frequently met with in the Cherra Limestone of Assam.

Genus — *Lithophyllum* Philippi, 1837

Lithophyllum sp.

Pl. 1, fig. 2

1979 *Lithophyllum* sp. Kar, p. 90, pl. 1, fig. 3

Description (from Kar, 1979) — Fragmentary remains of *Lithophyllum* observed in many thin sections. Thalli characterized by

presence of coaxial hypothallus and a layered perithallus. Cellular structure not well preserved.

Figured Specimen — B.S.I.P. slide no. 5920/1.

Occurrence — Fulra Limestone (Middle Eocene) exposed at Babia Hill.

Comparison and discussion — This *Lithophyllum* sp. shows some resemblance with *Lithophyllum prelichenoides* Lemoine (1917) as shown by Johnson and Adey (1965). *L. prelichenoides*, however, differs from the present fossil in having very well-developed perithallial cells and marked transverse septa in the coaxial cells.

PHANEROGAMS

FAMILY — COMBRETACEAE

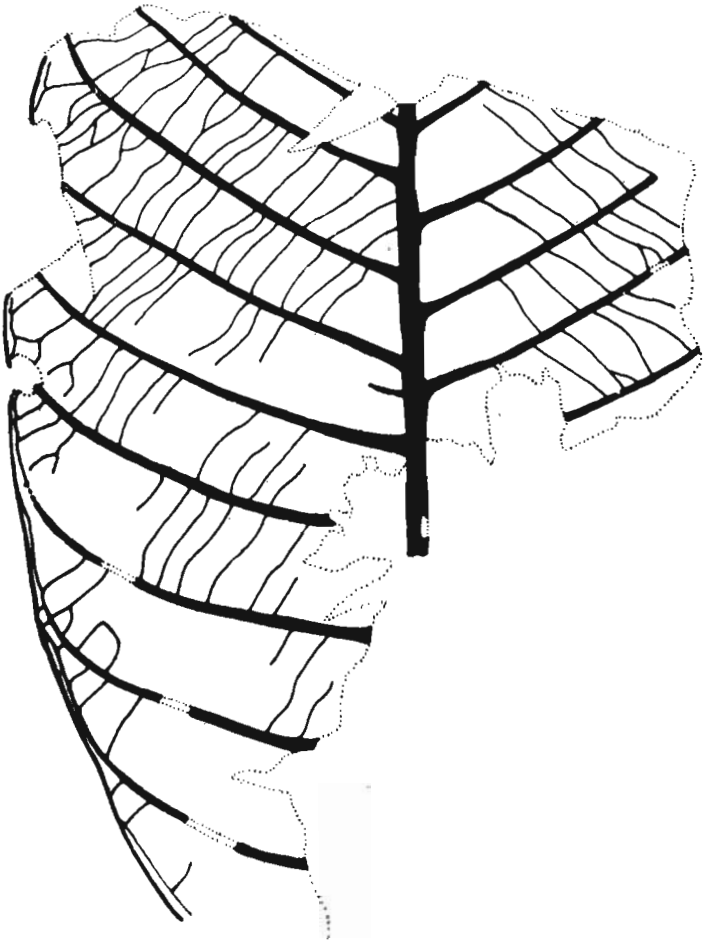
Genus — *Terminalia* Linn.

Terminalia panandhroensis Lakhanpal & Guleria

Pl. 2, fig. 1; Text-fig. 1

1981 *Terminalia panandhroensis* Lakhanpal & Guleria, p. 354, pl. 1, fig. 1.

Description (based on Lakhanpal & Guleria, 1981) — Leaf appearing to be symmetrical,



TEXT-FIG. 1 — *Terminalia panandhroensis*, leaf. Natural size.

elliptic-oblong, preserved lamina length 11.5 cm, maximum preserved width 9.5 cm; apex not preserved; base seemingly rounded; margin entire, slightly wavy; texture seemingly chartaceous; venation pinnate, eucamptodromous; primary vein (1°) massive; secondary veins (2°) appearing to run along the midrib for a short distance before diverging out, moderately thick, angle of divergence varying from 80° in the lower region to 60° in the upper, upturned very near the margin; tertiary veins (3°) fine, angle of origin OR to OA; pattern percurrent, prevalently unbranched, rarely branched, obliquely arranged in relation to mid-vein, arrangement predominantly opposite, close; higher order venation not seen.

Holotype — B.S.I.P. specimen no. 35385.

Occurrence — Panandhro.

Comparison and discussion — The above mentioned characters can be found in the leaves of *Terminalia* Linn. of Combretaceae and *Anthocephalus cadamba* Miq. of the family Rubiaceae. The leaves of *Anthocephalus cadamba* differ from the present fossil in having predominantly alternate arrangement of tertiaries unlike the opposite arrangement of the fossil. Moreover, tertiaries are relatively distantly placed in *A. cadamba* than in the fossil. On comparing the leaves of a number of species of *Terminalia* with the fossil it was found that *T. crenulata* Heyne ex Roth. and *T. coriacea* (Roxb.) W. & A. show the nearest resemblance in almost all the characters except the arrangement of tertiaries which is opposite to alternate in these two species whereas in the fossil it is predominantly opposite. It is difficult to differentiate the leaves of *T. coriacea* and *T. crenulata* morphologically. They can, however, be separated on the basis of their texture which is thicker in *T. coriacea* and thinner in *T. crenulata*. In this regard the fossil shows better comparison with the leaves of *T. crenulata*.

Terminalia panandhroensis is the first known species of *Terminalia* from India based on fossil leaves. Leaf impressions showing affinities with *Terminalia* have been reported by Lakhanpal (1970, p. 683) from the Siwalik beds of India, although no specific name has been assigned to them.

The genus *Terminalia* comprises 250 species (Willis, 1973, p. 1136). They are large trees, widely distributed in the tropics of the world. *Terminalia crenulata* is a large deciduous tree and is found in the central, southern and western India, Bihar, Orissa, Assam and Burma (Ramesh Rao & Purkayastha, 1972, p. 199).

FAMILY — MYRTACEAE

Genus — *Syzygium* Gaertn.

Syzygium kachchhense Lakhanpal & Guleria

Pl. 2, fig. 5; Pl. 3, figs 1, 2

1981 *Syzygium kachchhense* Lakhanpal & Guleria, p. 356, pl. 1, fig. 5; pl. 2, fig. 7.

Description (from Lakhanpal & Guleria, 1981) — Leaf slightly asymmetrical, ovate-elliptic, lamina length 7.0-9.5 cm, maximum width 5.0-5.5 cm; apex short acuminate; base not preserved; margin entire; texture seemingly chartaceous; petiole not preserved; venation pinnate, brochidodromous; primary vein (1°) single, stout, slightly curved; secondary vein (2°) with angle of divergence varying from right angle (90°) in the basal region to acute (60°) in the apical, moderately thick, uniformly curved, unbranched, forming intramarginal vein; intersecondary veins single; tertiary veins (3°) fine, abundant, angle of origin AO to RR; pattern random to orthogonal, at places randomly oriented; areoles well-developed, oriented, mostly quadrangular, rarely triangular, small, veinlets not seen.

Holotype — B.S.I.P. specimen no. 35889.

Occurrence — Panandhro.

Comparison and discussion — The closely placed secondaries along with intersecondaries and the presence of intramarginal veins are the important features of the fossil. These characters can be seen in the leaves of *Calophyllum* Linn. and *Garcinia* Linn. of the Guttiferae; *Chrysophyllum* Linn. of Sapotaceae; *Ficus* Linn. of Moraceae and *Syzygium* Gaertn. of the family Myrtaceae. *Calophyllum* leaves differ from our fossil in being distinctly coriaceous, with much more closely placed secondaries and obtuse apex. Likewise *Garcinia speciosa*, which shows apparent similarity with fossil also differs in thickness and in the angle of divergence of secondaries. Similarly, the

leaves of two species of *Chrysophyllum*, *C. oliviforme* Linn. and *C. roxburghii* G. Don., show some resemblance but they differ in being coriaceous and in the arrangement of tertiary venation. Among the number of *Ficus* species compared, the leaves of *F. benjamina* Linn. and *F. elastica* Roxb. come closer to the fossil. However, their leaves are quite thick and coriaceous as compared to the fossil. In addition, the meshes formed by tertiaries in *F. elastica* are much larger than in the present fossil. The leaves of *Syzygium* show the best resemblance with the fossil in shape, size, apex, texture and venation. A large number of *Syzygium* species were compared with the fossil but none of them was found identical. The Panandhro fossil perhaps represents an ancestral form of *Syzygium*.

The authors are aware of two species of *Syzygium*, viz., *S. chaneyi* Huzioka & Takahasi (1970) from the Eocene of Japan and *S. floribundoides* Engelhardt from the mid-Eocene of West Germany (Müller, 1934, p. 110). Leaf remains of *Syzygium* have also been recorded by Lakhanpal (1970, p. 683) from the Siwalik beds of India but its detailed description is not available. Besides, there are records of a number of leaf impressions from the Old World which have been described as species of *Eugenia*. According to Schmid (1972) they should be considered as species of *Syzygium*. All these above fossil leaves of *Syzygium* have been compared with *S. kachchhense* but found to be distinct (Lakhanpal & Guleria, 1981, pp. 356, 357).

The genus *Syzygium* consists of trees, shrubs and rarely climbers and occurs in various kinds of tropical forests. They are water loving plants which thrive in moist localities along the banks or in the beds of streams. According to Santapau and Henry (1973, p. 166) the genus in India is represented by more than 50 species.

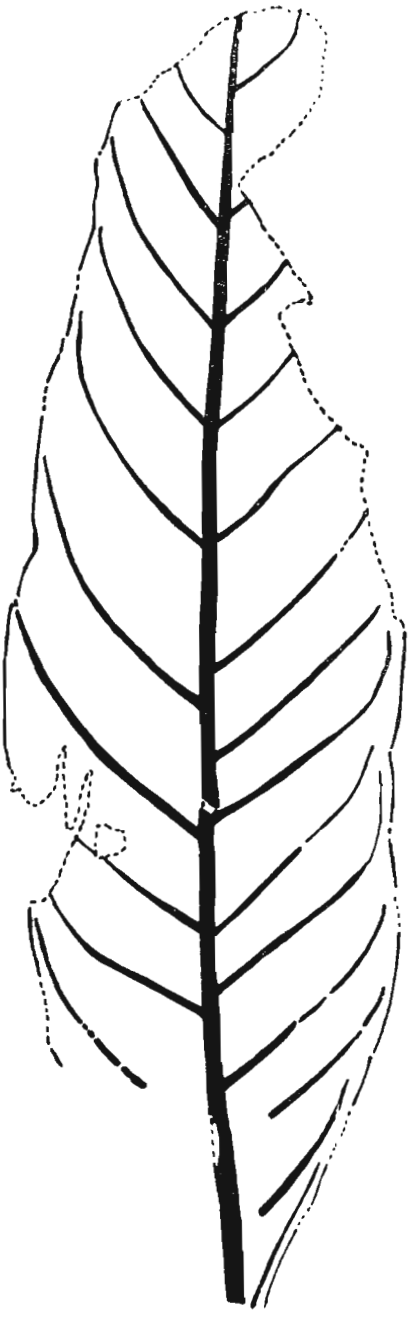
FAMILY — LYTHRACEAE

Genus — *Lagerstroemia* Linn.

Lagerstroemia patelii Lakhanpal & Guleria

Pl. 4, fig. 1; Text-fig. 2

1981 *Lagerstroemia patelii* Lakhanpal & Guleria, p. 357, pl. 3, fig. 10



TEXT-FIG. 2 — *Lagerstroemia patelii*, leaf. Natural size.

Description (from Lakhanpal & Guleria, 1981) — Leaf symmetrical, narrow elliptic; preserved lamina length 16.9 cm, maximum

width 5.3 cm; apex broken; base broken (seemingly cuneate); margin entire, slightly wavy; texture chartaceous; petiole unpreserved; venation pinnate, brochidodromous; primary vein (1°) single, stout, slightly curved; secondary veins (2°) with angle of divergence acute (70°-50°), 70° at the basal region and gradually decreasing upwards, relatively fine, curving upward, rarely branched; intersecondary veins present, appearing simple; tertiary veins (3°) and higher order venation not visible.

Holotype — B.S.I.P. specimen no. 35393.

Occurrence — Panandhro.

Comparison and discussion — The characteristic features of fossil are: seemingly symmetrical shape, narrow elliptic form; entire, slightly wavy margin; seemingly cuneate base and pinnate brochidodromous venation. These characters can be seen in the leaves of *Mangifera* Linn., *Saraca* Linn. and *Lagerstroemia* Linn. The leaves of *Mangifera* differ in the angle of divergence and curvature of the secondaries. Although *Saraca indica* Linn. leaves show close resemblance with the fossil, they differ in having eucamptodromous venation as compared to the brochidodromous venation in the fossil. Of the various species of *Lagerstroemia* examined, *L. tomentosa* Presl., *L. floribunda* Jack and *L. speciosa* L. Pers. show close similarity with the fossil. The leaves of *L. tomentosa* and *L. floribunda* are smaller in size than the fossil. In general the leaves of *L. speciosa* show closest resemblance with the fossil.

The authors are aware of only three records of fossil leaves of *Lagerstroemia*. Two of them are reported from the Deccan Intertrappean beds by Shukla (1950) and Trivedi (1956) and the third from the Siwalik beds of Himachal Pradesh by Lakhanpal and Dayal (1966). As the leaf-impressions described by Shukla (1950) and Trivedi (1956) are comparable with *Lagerstroemia indica*, they are different from the present fossil which resembles *L. speciosa*. The fossil *Lagerstroemia* of Lakhanpal and Dayal (1966) being about 1/3rd of the size of the present fossil is clearly distinct. Thus the present fossil is different from all of them.

According to Santapau and Henry (1973, p. 92) there are 10 species of *Lagerstroemia* in India. *Lagerstroemia speciosa* with which the fossil resembles is found in Assam, Chittagong, Lower Burma, Western Ghats, Srilanka and Malay Peninsula, mainly near river banks.

Family — Lauraceae

Genus — *Cinnamomum* Schaeffer

Cinnamomum eokachchhensis Lakhanpal & Guleria

Pl. 2, figs 2-4; Text-fig. 3A-C

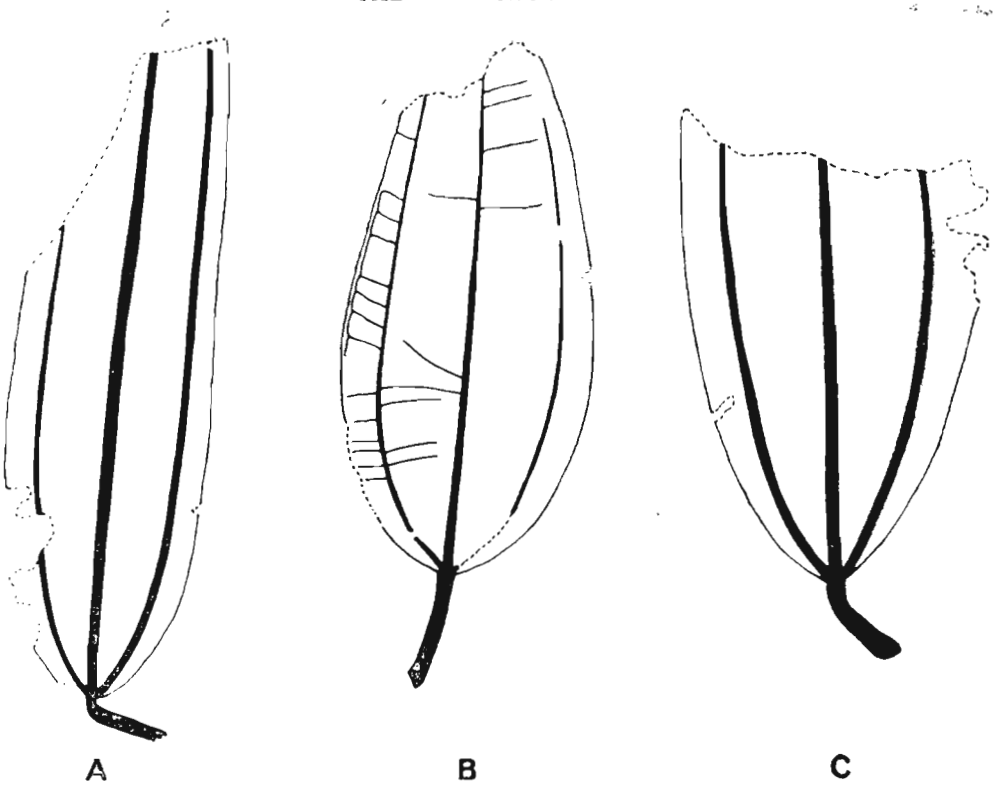
1981 *Cinnamomum eokachchhensis* Lakhanpal & Guleria, p. 358, pl. 1, figs 2-4.

Description (from Lakhanpal & Guleria, 1981) — Leaves symmetrical, elliptic to elongate-ovate; lamina length varying from about 5.5-9.5 cm, maximum width 2.8-4.0 cm; apex broken; base symmetrical, obtuse to almost rounded; margin entire; texture seemingly coriaceous; attachment of petiole normal, preserved petiole length 0.2-2.0 cm; venation basal acrodromous, perfect; primary veins (1°) three, moderate to stout, middle vein straight, two lateral primaries slightly curved, unbranched; secondaries (2°) very fine, visible on careful observation, running more or less horizontally, slightly obliquely, straight to slightly curved, unbranched, those emerging from lateral primaries on fusing forming a fine continuous vein (intramarginal vein) along the margin; tertiaries (3°) still finer, forming numerous very fine meshes; areoles imperfect, veinlets not seen.

Holotype — B.S.I.P. specimen no. 35386.

Occurrence — Panandhro.

Comparison and discussion — The most diagnostic character of the fossil is the acrodromous pattern of venation which is found in the leaves of a number of dicot families (Lakhanpal & Guleria, 1981, pp. 358, 359). Leaves showing this type of venation together with the characters referred to above are found in *Cocculus* DC. of Menispermaceae; *Smilax* Linn. of Smilacaceae; *Lindera* Thunb., *Litsea* Lamk., *Neolitsea* (Benth.) Merrill and *Cinnamomum* Schaeffer of Lauraceae. Although showing broad resemblance the leaves of all these genera differ from our fossil in one or more important characters except those of



TEXT-FIG. 3A-C — *Cinnamomum eokachchhensis*, leaves. Natural size.

Cinnamomum (Lakhanpal & Guleria, 1981, pp. 358, 359). Among the large number of *Cinnamomum* species examined, *C. zeylanicum* shows the closest resemblance with the fossil.

In addition to the present species, four more species of fossil *Cinnamomum* based on their leaves are known from India. They are: *Cinnamomum* sp. cf. *C. tamala* Nees from the Middle Siwalik beds of Darjeeling, West Bengal (Pathak, 1969); *Cinnamomum miokachchhensis* from the Lower Miocene beds of Kachchh (Lakhanpal & Guleria, 1982); *C. palaeotamala* from the Siwalik beds of Bihar Nepal boundary in the West Champaran District, Bihar (Lakhanpal & Awasthi, 1984) and *C. tamala* reported by Middlemiss (1911) from the Lower Karewa beds of Kashmir. However, Puri (1948) reinvestigated the specimens of *C. tamala* of Middlemiss and found them belonging to seven different genera other than *Cinnamomum*. Both the upper and lower portions of the *Cinnamomum* sp. described by Pathak (1969) are broken and the secondaries in it arise at acute angles as compared to the present fossil in which they arise more or less at right angles. Further, the intramarginal vein is absent in Pathak's specimen. *Cinnamomum miokachchhensis* (Lakhanpal & Guleria, 1982) differs from the present fossil in its smaller size, relatively thin texture, normally acute base and in the presence of prominent secondaries. In *Cinnamomum palaeotamala* Lakhanpal & Awasthi (1984) the lateral primaries are suprabasal in origin as compared to their basal origin in the present fossil. Further, intramarginal vein is present in the present species which, however, is not visible in *C. palaeotamala*.

The genus *Cinnamomum* consists of 250 species of evergreen trees and shrubs and is confined to tropical and subtropical regions of East Asia and Indomalaya. Sixteen species of *Cinnamomum* have been reported from India (Santapau & Henry, 1973, p. 39). *Cinnamomum zeylanicum*, with which the fossil shows similarity, is a large tree and is

found in the Western Ghats and the adjoining hill ranges, from Konkan southwards and also in Tenasserim (Brandis, 1906, p. 533).

FAMILX — MORACEAE

Genus — *Ficus* Linn.

Ficus kachchhensis Lakhanpal & Guleria

Pl. 3, fig. 3; Text-fig. 4A-B

1981 *Ficus kachchhensis* Lakhanpal & Guleria, p. 361, pl. 2, fig. 8.

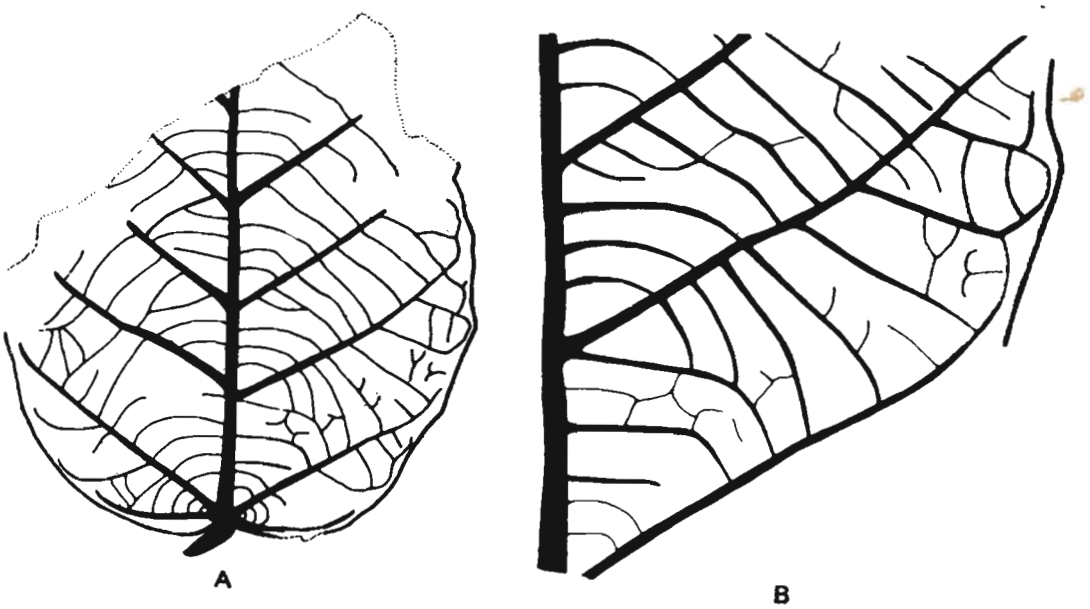
Description (from Lakhanpal & Guleria, 1981) — Leaf symmetrical, seemingly wide ovate; preserved lamina length 8.8 cm, maximum width 8.5 cm; apex not preserved; base cordate; margin entire, slightly undulating; texture thick; attachment of petiole normal; preserved length 0.7 cm; venation pinnate, eucamptodromous; primary vein (1°) simple stout, course more or less straight; secondary veins (2°) angle of divergence acute, moderate (60°-50°), relatively less thick than primary vein; uniformly curved, unbranched; intersecondary veins absent; tertiary veins (3°) angle of origin RA to RR, course sinuosus, obliquely arranged in relation to mid-vein, arrangement predominantly alternate, close to distant; quaternary veins (4°) — size normal, course varying from relatively random to orthogonal; marginal ultimate venation fimbriate; areoles well-developed, shape triangular to pentagonal, size very large, veinlets not seen.

Holotype — B.S.I.P. specimen no. 35391.

Occurrence — Panandhro.

Comparison and discussion — The shape of the fossil leaf, its cordate base, and the type of venation are found in a few species of the genus *Ficus* Linn. of the family Moraceae. In these characters the *Ficus* spp. resembling the present fossil are: *Ficus benghalensis* Linn., *F. roxburghii* Wall., *F. rotundifolia* Roxb., *F. hookeri* Miq., *F. hispida* L. f., *F. laevis* Blume, *F. varigata* Blume, *F. palmata* Forsk., and *F. tomentosa* Roxb. Among these, *Ficus tomentosa* shows closest resemblance with the present fossil.

So far seven species of *Ficus* are known from India based on the fossil leaves, viz., *F. cunia* Puri (1947), Gupta & Jiwan (1972), *F. nemoralis* Puri (1948), *F. precunia* Lakhanpal (1969), *F. arnottiana* and *F. glomerata*



TEXT-FIG. 4 — **A,** *Ficus kachchhensis*, leaf. Natural size; **B,** Part of text-figure 4a enlarged showing details of venation. × 2.

Mahajan & Mahabale (1973), *F. khariensis* Lakhanpal & Guleria (1982) and *F. champarense* Lakhanpal & Awasthi (1984). Of these, only *F. arnottiana* shows apparent resemblance with the present fossil in having more or less similar shape and base but differs in the curvature of secondary veins and in having conspicuous submarginal arches formed by the secondaries. Thus, none of the known Indian fossil species of *Ficus* resembles the present fossil.

Ficus is a very big genus, widely distributed throughout the tropics of both the hemispheres. Santapau and Henry (1973, p. 67) have listed 70 species from India. *Ficus tomentosa*, with which *Ficus kachchhensis* shows resemblance, is found in Bundelkhand, Banda, Bihar, Chota Nagpur, Central India and western Peninsula (Brandis, 1906, p. 601).

Genus — ***Dicotylophyllum*** **Saporta, 1894**

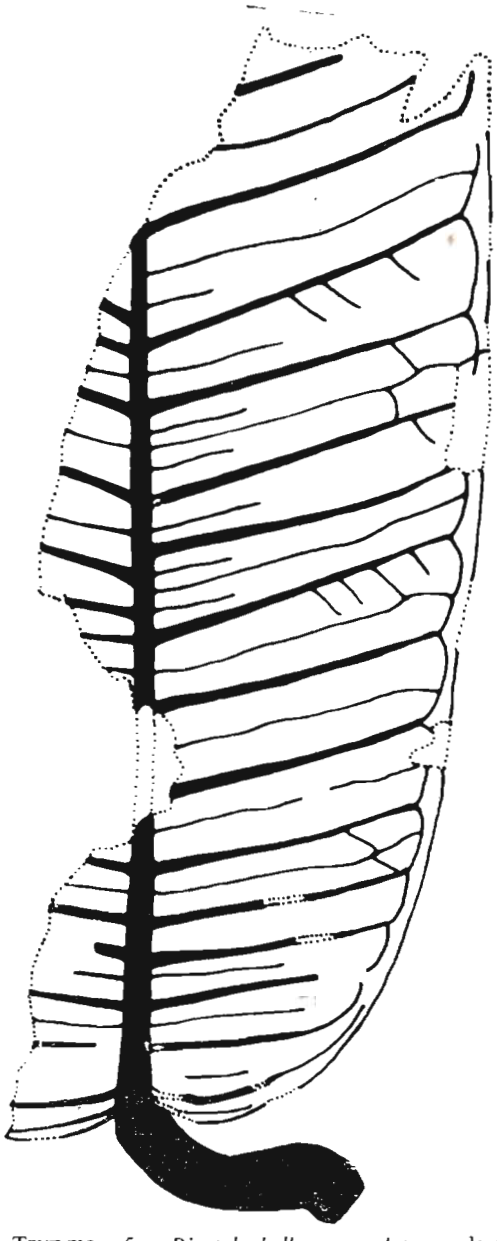
Dicotylophyllum cordatum Lakhanpal & Guleria

Pl. 4, fig. 2; Text-fig. 5

1981 *Dicotylophyllum cordatum* Lakhanpal & Guleria, p. 363, pl. 3, fig. 11.

Description (based on Lakhanpal & Guleria, 1981) — Leaf appearing symmetrical, seemingly oblong, maximum preserved lamina length 14.4 cm, maximum width on one side of the midrib about 4.5 cm; apex broken; base cordate, margin entire, straight to slightly wavy; texture appearing to be thick chartaceous; petiole thick (fleshy), about 8.0 mm wide, about 3.5 cm long; venation pinnate, brochidodromous; primary veins (1°) single, stout, slightly curved; secondary vein (2°) with wide acute (85°-70°) angle of divergence, 85° in the basal region and gradually decreasing upwards, moderately thick, more or less uniformly curved, joining superadjacent secondary at right angle to slightly obtuse angle, forming intramarginal veins; intersecondary veins present, simple, reaching almost up to intramarginal vein; tertiary veins (3°) with angle of origin AA, AR or rarely RR, joining intersecondaries, course simple, slightly obliquely arranged in relation to midvein, alternate to opposite in arrangement, distant to close; quaternary veins (4°) thin, course more or less orthogonal; ultimate marginal venation fimbriate; areoles well-developed, oriented, usually quadrangular, small; veinlets not seen.

Holotype — B.S.I.P. specimen no. 35394,



TEXT-FIG. 5 — *Dicotylophyllum cordatum*, leaf. Natural size.

Occurrence — Panandhro.

Comparison and discussion — The leaves of *Plumeria* spp. of the family Apocynaceae; *Duabanga grandiflora* (Roxb.) Walp. (=*D. sonneratioides* Buch-Ham) of Sonneratiaceae; *Tupidanthus calyptratus* Hook. f. & Thoms. of Araliaceae and *Ficus elastica* Roxb. of Moraceae show fairly close resemblance with the fossil in almost all the characters except the base. In the fossil leaf the base is cordate whereas in none of these living species the leaves have a cordate base.

The present fossil does not resemble any of the earlier known fossil angiospermous leaves (Lakhanpal & Guleria, 1981, p. 364) from India. As the present fossil is a dicot leaf whose natural affinities could not be ascertained, it has been placed under the form genus *Dicotylophyllum* Saporta.

Dicotylophyllum panandhroensis Lakhanpal & Guleria

Pl. 5, fig. 1; Text-fig. 6

1981 *Dicotylophyllum panandhroensis* Lakhanpal & Guleria, p. 364, pl. 4, fig. 12.

Description (from Lakhanpal & Guleria, 1981) — Leaf slightly asymmetrical, seemingly elliptic; preserved lamina length 13.8 cm, maximum width 11.2 cm; apex broken; base obtuse, inequilateral; margin entire, slightly wavy; texture coriaceous or thickly chartaceous; petiole normal, preserved length 1.0 cm; venation pinnate, appearing craspedodromous; primary vein (1°) single, stout, slightly curved; secondary veins (2°) diverging more or less at right angles, thickness relatively less than that of the primary vein, more or less straight, sometimes slightly curved up near the margin, rarely also bifurcating close to the margin; intersecondary veins present, faint, simple; tertiary veins (3°) very faint, rarely visible, angle of origin almost right angle, distantly arranged; higher order venation not seen.

Holotype — B.S.I.P. specimen no. 35395.

Occurrence — Panandhro.

Comparison and discussion — Some species of *Barringtonia* J. R. & G. Frost of Barringtoniaceae and *Melanorrhoea* Wall. and *Semecarpus* L.f. of Anacardiaceae have similar type of leaves. The leaves of *Barringtonia* which show apparent resemblance with the fossil, differ distinctly in the shape of the lower half of the leaf. Moreover, the petiole in *Barringtonia* is very small. *Semecarpus anacardium* L.f. leaves, which show some resemblance with the present fossil, differ from it in their bases and also in the angle of divergence of the secondaries. Among the various species of *Melanorrhoea* examined, the leaves of *M. usitata* Wall. show close resemblance with the fossil. However, the base in *M. usitata* leaves is cuneate and shows a little prolongation as compared to the present fossil in which the base is obtuse and does not show any prolongation.

None of the earlier known fossil leaves shows any similarity with the present fossil. Further, the fossil leaves reported as dicot leaves *Dicotylophyllum* and *Phyllites* (Lakhanpal & Guleria, 1981, p. 364) also do not show any similarity with the present fossil. Being a dicot leaf, the fossil has been placed under the artificial genus *Dicotylophyllum* Saporta.

Dicotylophyllum quadrinervatum Lakhanpal & Guleria

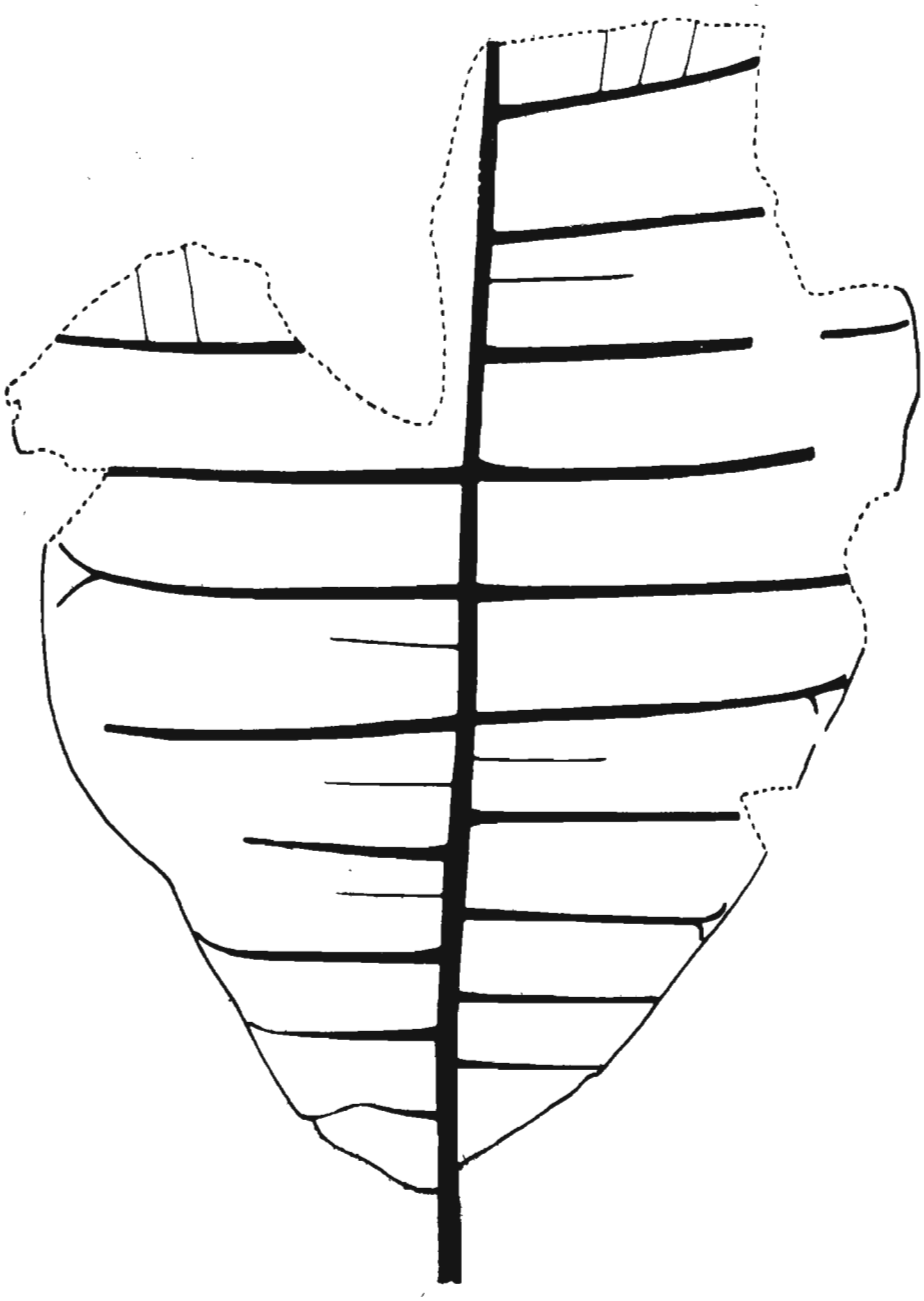
Pl. 3, fig. 4; Text-fig. 7A-B

1981 *Dicotylophyllum quadrinervatum* Lakhanpal & Guleria, p. 365, pl. 2, fig. 9

Description (from Lakhanpal & Guleria, 1981) — Leaf appearing to be symmetrical, ? wide elliptic; preserved lamina length 8.0 cm, maximum preserved width 5.8 cm; apex not preserved; base broad obtuse, slightly cuneate; margin preserved only close to the base, entire; texture chartaceous; petiole normal, curved, preserved length 1.5 cm; venation actinodromous, primary veins radiation basal, development perfect, seemingly marginal; primary veins (1°) four, stout, slightly curved, branched, branches arising at acute angles, moving upwards; secondary veins (2°) distantly placed, arising from primaries and their branches, joining the two adjacent primaries or other secondaries, fine, curved to wavy, two successive secondaries sometimes joining each other in the middle; tertiary veins (3°) fine, percurrent or occasionally joining primaries directly, mostly simple, wavy, approximately at right angle to the primaries; higher order venation not seen.

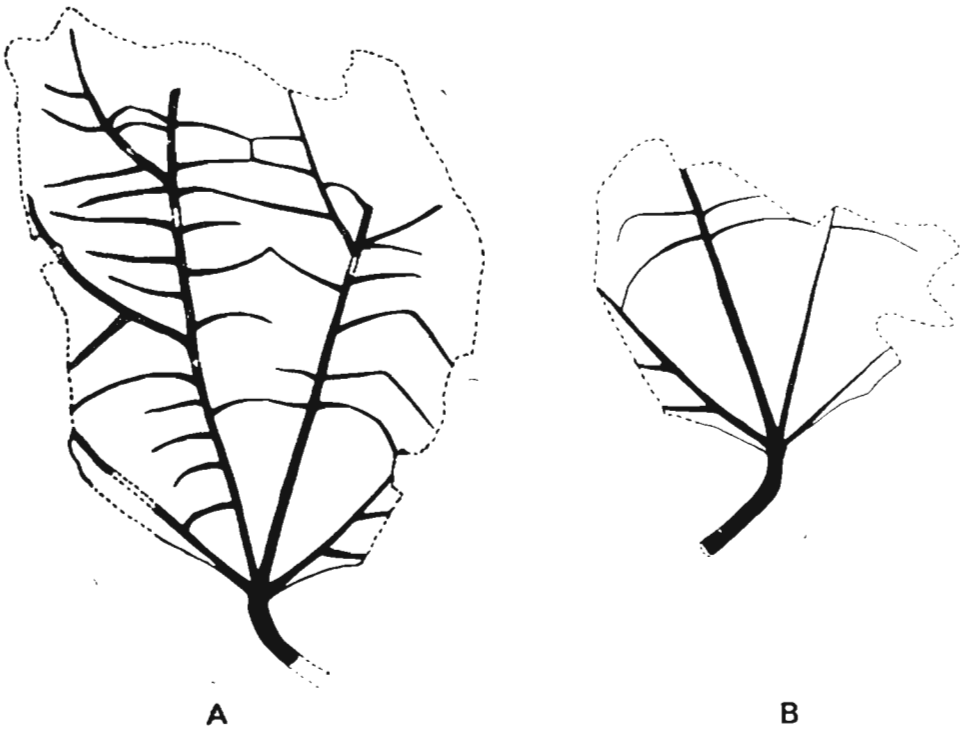
Holotype — B.S.I.P. specimen no. 35392.

Occurrence — Panandhro.



TEXT-FIG. 6 — *Dicotylophyllum panandhroensis* leaf. Natural size.

Comparison and discussion — It has not been possible to compare the present fossil with the leaf of any living plant due to its characteristic actinodromous venation with four primaries and their apparently divergent arrangement. Simliarly it does not resemble any known fossil leaf described so far. As it is doubtlessly a dicot leaf and its affinities are uncertain it has been named as a new species of *Dicotylophyllum*.



TEXT-FIG. 7 — **A**, *Dicotylophyllum quadrinervatum*, leaf. Natural size; **B**, counterpart of the specimen shown in text-figure 7a. Natural size.

FAMILY — PANDANACEAE

Genus — *Pandanus* L.f. ex Stickman

Pandanus eocenicus Guleria & Lakhanpal

Pl. 6, figs 1, 2; Text-fig. 8

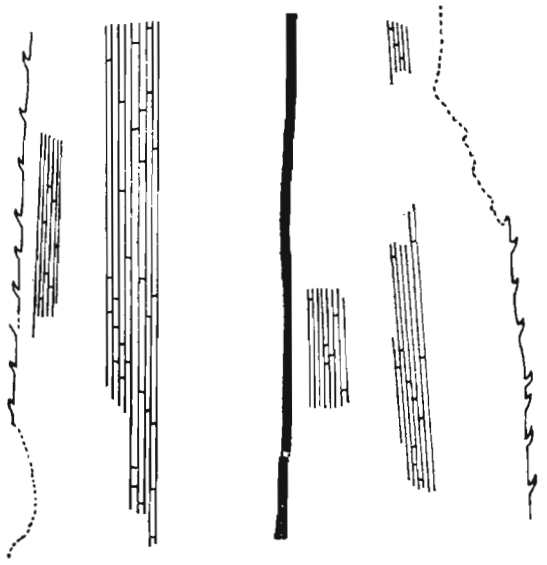
1984 *Pandanus eocenicus* Guleria & Lakhanpal, p. 115, pl. 1, figs 1, 2; text-fig. 1.

Description (from Guleria & Lakhanpal, 1984) — Leaf symmetrical, ensiform, lamina length 12.3 cm, width 3.8-4.8 cm; apex and base not preserved; margin spinulose except at the lower portion where no spinules are seen, spinules simple, 1.0-1.5 mm long, 2.0-4.0 mm apart; texture seemingly coriaceous; venation parallel; midrib prominent; secondaries closely placed, about 50 on either side of the midrib, connected by short straight tertiary cross veins.

Holotype — B.S.I.P. specimen no. 35384.

Occurrence — Panandhro.

Comparison and discussion — The above mentioned characters can be seen in the modern leaves of *Ananas* Mill. of Bromeliaceae, *Calamus* Linn. of Palmae and *Pandanus* Linn. of Pandanaceae. In most comparable species of *Calamus* the leaves are narrower, in some spines are bigger and generally placed at greater intervals. Further, the secondaries are fewer and distantly placed and the tertiary cross-veins are long and wavy. *Ananas* and *Pandanus* show very close similarity with the present fossil. Of the two genera, the fossil most likely belongs to *Pandanus* rather than to *Ananas* in view of their present day distribution. *Ananas* is native to tropical America. Further, the other taxa occurring along with the present fossil, form a more natural association with *Pandanus* than with *Ananas*. Leaves of a number of *Pandanus* species were examined and compared with the present fossil. Out of these, *P. diversus* John, *P. furcatus* Roxb. and *P. tectorius* Solander show the best resemblance with the fossil. It is difficult to separate these three species on the basis of leaf morphology. The present fossil leaf, *Pandanus eocenicus* is the only record of *Pandanus* from India.



TEXT-FIG. 8 — *Pandanus eocenicus*, a part of leaf enlarged showing spines and details of venation, × 1.5.

According to Santapau and Henry (1973, p. 123) there are 36 species of *Pandanus* in India. Regarding the three species resembling the present fossil *Pandanus diversus* is confined to the Himalayan region (John, 1972) in Assam, Laikul, Cachar up to 615 m and is tree-like in habit. *P. furcatus* occurs in Sikkim, and is common in Ghat forests of Belgaum and North Kanara. It is a low gregarious tree, forming dense, almost impenetrable thickets in marshy places, near water courses. *P. tectorius* occurs in Sunderbans, the Andamans and on the sea coasts of Peninsula on both sides, usually forming a belt above high water mark. *Pandanus* does not grow in the present day flora of Kachchh except in the cultivated form.

MIOCENE MEGAFOSSILS

ALGAE

FAMILY — CORALLINACEAE

Genus — *Lithophyllum* Philippi, 1837

Lithophyllum aff. *L. kladosum* Johnson, 1954

Pl. 7, figs 1, 2

1974 *Lithophyllum* aff. *L. kladosum*, Pal & Ghosh, p. 189, pl. 1, figs 1, 2,

Description (from Pal & Ghosh, 1974) — Fragments of long slender branches showing well-developed medullary hypothallus and marginal perithallus. Hypothallus formed of arched layers of cells, length 16-40 μm, width 12-20 μm. Perithallic cells nearly square or rectangular, length 16-20 μm, width 10-16 μm. Conceptacles of moderate size, diameter 280-320 μm, height 136-160 μm. Conceptacles show single aperture.

Figured Specimen — Calcutta University, Botany Department, slide no. C/05.

Occurrence — Khari Series (Lower Miocene) exposed near Waior.

Comparison and discussion — The fossil closely compares with *Lithophyllum kladosum* reported from the Lower Miocene of Bikini and Guam by Johnson (1954, 1964). The dimensions of the cells and of sporangia are well within the range observed in *L. kladosum*. However, the sporangia and the hypothallic cells in the present fossil are relatively smaller than those in *L. kladosum*.

Genus — *Mesophyllum* Lemoine, 1928

Mesophyllum commune Lemoine, 1939

Pl. 7, figs 3, 4; Pl. 8, fig. 1

1974 *Mesophyllum commune*, Pal & Ghosh, p. 190, pl. 1, fig. 3; pl. 2, fig. 5,

Description (from Pal & Ghosh, 1974) — Thallus develops short thick branches probably from basal crust. Branches composed of medullary hypothallus and marginal perithallial tissue showing pronounced growth zones, each zone formed of 6-8 layers of rectangular cells. The hypothallial cells are 16-24 μm long and 12 μm wide. The perithallial cells squarish to rectangular 12-16×10-12 μm. Conceptacles numerous, 136-140-160 μm in height and 320-360-800 μm in diameter.

Figured Specimen — Calcutta University, Botany Department, slide nos. CF/03 and CF/05.

Occurrence — Khari Series (Lower Miocene) exposed near Waior.

Comparison and discussion — The fossil specimens from Kachchh show best resemblance with *Mesophyllum commune* described by Lemoine (1939) from the Miocene of Algeria except for some minor variable differences in the sporangial diameter. Hence, the present specimens had been assigned to *M. commune* Lemoine (1939). This species has also been reported by Johnson (1964) from the Maemong Limestone Member (Lower Miocene) of the Umatac Formation of Guam.

Genus — *Aethesolithon* Johnson, 1964

Aethesolithon problematicum Johnson, 1964

Pl. 8, figs 2, 3

1974 *Aethesolithon problematicum*, Pal & Ghosh, p. 190, pl. 2, figs 2, 3.

Description (from Pal & Ghosh, 1974) — Plant starts as irregular crust with warty protuberances or small mamillae and develops branches. Branches are 5 cm or more in length and show well-developed medullary hypothallus and marginal perithallus. Thickness of medullary hypothallus 1200-1500 μ; strongly arched layers arranged in definite growth zones which in some specimens appear as vertically elongated hexagons; cells alternate in position in successive rows so that one cell fits between the points of those above and below. Usually the lowest layer in a zone contains largest cells, uppermost the smallest. In a given layer, cells also decrease in size from centre to margins. Cells are usually 40-56×20-40 μ. Marginal perithallus of branches formed of very irregular layers, commonly 2 or 3 layers to a growth zone. Cells rounded to polygonal. Cells are 16-20×8-20 μ. Conceptacles develop in outer layers of crusts and in perithallic tissue of branches, small and highly arched. Number of opening not very clear but arching suggests a single opening. Conceptacles are 160-200 μ in length and 96-112 μ in diameter.

Figured Specimen — Calcutta University, Botany Department, slide no. CF/03.

Occurrence — Khari Series (Lower Miocene) exposed near Waior.

Comparison and discussion — The fossil shows close similarity with *Aethesolithon problematicum* described by Johnson (1964) from the Bonya Limestone (Lower Miocene) of Guam except for the hypothallic cells which are generally short in the present material.

Aethesolithon cutchensis Pal & Ghosh, 1974

Pl. 8, fig. 4; Pl. 9, fig. 1

1974 *Aethesolithon cutchensis* Pal & Ghosh, p. 190, pl. 2, fig. 8; pl. 3, fig. 9.

Description (from Pal & Ghosh, 1974) — Plant starts as irregular crust and then develops branches. Branches attain 3-4 mm length with diameter of about 1200 μ. Thickness of medullary hypothallus 800-1000 μ. Strongly arched layers arranged in definite growth zones which appear like thick lenses, each zone with 3-5 layers or large polygonal cells which appear as vertically elongated hexagons. The lowest layer in a zone shows largest cells, and the uppermost the smallest. Thus the variation in size of cells in a zone from bottom upwards is as follows: 40×32 μ, 32×24 μ, 24×16 μ. Marginal perithallus of branches formed of very irregular layers, commonly 2 or 3 layers to a growth zone. Cells rectangular 16-32×8-20 μ. Cells in lenses larger and polygonal, 24×32×16-24 μ. Conceptacles arched, 160 μ in height and 640 μ in diameter. Conceptacles probably open with a single aperture.

Holotype — Calcutta University, Botany Department, slide nos. C/03, C/04.

Occurrence — Khari Series (Lower Miocene) exposed near Waior.

Comparison and discussion — Among the different species of *Aethesolithon*, the fossil

show close resemblance with *A. problematicum* Johnson (1964). The present species, however, differs from *A. problematicum* in having smaller cells in the hypothallial tissue and the larger diameter of the conceptacles.

Genus — *Archaeoporolithon* Pal & Ghosh, 1974

Archaeoporolithon miocenicum Pal & Ghosh, 1974

Pl. 9, figs 2-4

1974 *Archaeoporolithon miocenicum* Pal & Ghosh, p. 191, pl. 3, figs 10, 11.

Description (from Pal & Ghosh, 1974) — Plants crustose, often branching upwards. Crusts show basal hypothallus of curved rows of cells, 12-29 × 12-18 μ. Hypothallus is sometimes thin, the cells appearing as irregularly arranged. The perithallus is with heterocysts. The perithallial cells are 16-32 × 18-24 μ. The megacells occur in lenses up to 5 cells high. These sometimes occur as layers parallel to the perithallial cell threads. Often the lenses extend with decreased height on either side parallel to the substrate. Conceptacles are small with a single opening, usually 80-96 μ high and 272-280 μ in diameter.

Holotype — Calcutta University, Botany Department slide nos. FC/1 and FC/2.

Occurrence — Khari Series (Lower Miocene) exposed near Waior.

Comparison and discussion — The nature of the tissue and the conceptacle with single aperture place the fossil under the tribe Lithophyleae. The most characteristic feature of the *Archaeoporolithon* is the presence of thick lenticular groups of megacells in the perithallial tissue. The absence of these cells in *Lithophyllum* differentiates it from the present genus. The other closely comparable genera, viz., *Goniolithon*, *Porolithon* and *Paraporolithon* can also be reasonably differentiated from the present genus (Pal & Ghosh, 1974, p. 191). According to Pal and Ghosh (1974) *Archaeoporolithon* evolved from *Lithophyllum* during Lower Miocene and it is possibly ancestral to *Goniolithon*, *Porolithon* and *Paraporolithon*. This is different from the earlier view of Johnson (in Johnson & Adey, 1965, p. 12) according to which *Porolithon* and *Goniolithon* appear to have developed from *Lithophyllum* during the Miocene.

PHANEROGAMS

FAMILY — RUTACEAE

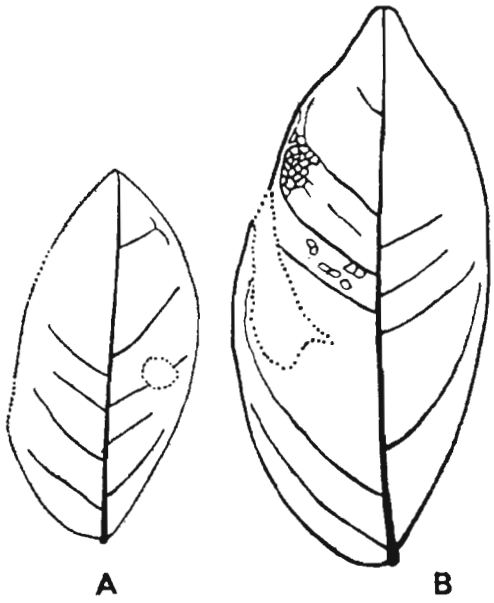
Genus — *Murraya* Koen. ex L.

Murraya khariensis Lakhanpal & Guleria

Pl. 10, figs 1, 2; Text-fig. 9A, B

1982 *Murraya khariensis* Lakhanpal & Guleria, p. 280, pl. 1, figs 1, 2; text-fig. 1A, B.

Description (from Lakhanpal & Guleria, 1982)—Leaflets asymmetrical, elliptic; lamina about 3.4-5.0 cm in length and 1.6-2.4 cm in width; apex blunt acute to short acuminate; base asymmetrical; margin entire; texture thick, smooth; petiolule hardly preserved; venation pinnate, eucamptodromous to brochidodromous, preservation poor; primary veins (1°) single, size moderate, slightly curved; secondary veins (2°) — angle of divergence acute 50°-60°, fine, curved, rarely branched; tertiary veins (3°) forming fine meshes, pattern random to orthogonal reticulate; areoles well-developed, appearing



TEXT-FIG. 9A, B — *Murraya khariensis*, leaf. Natural size.

triangular to pentagonal; veinlets not seen.

Holotype — B.S.I.P. specimen no. 35416.

Paratype — B.S.I.P. specimen no. 35417.

Occurrence — Khari Nadi Bed (near Goyela-Mokra).

Comparison and discussion — The above noted characters of the fossil can be seen in the leaves or leaflets of some of the species of *Zanthoxylum* Linn., *Paramignya beddomei* Tanaka, *Aegle marmelos* Correa, *Murraya koenigii* Spreng. and *M. Paniculata* (Linn.) Jack. (Syn. *M. exotica* Linn.) of the family Rutaceae. The leaves of *Paramignya beddomei* and leaflets of *Xanthoxylum* spp. differ from the present fossil in having longer apex. Leaflets of *Aegle marmelos* differ in having crenate margin as compared to the smooth margin of fossil. Of the two species of *Murraya*, the leaflets of *M. koenigii* differ in having serrated margin, relatively longer apex and chartaceous texture. The leaflets of *M. paniculata* show nearest similarity with the fossil in all the characters except the petiolule which is bigger in the living species.

Murraya khariensis is the first fossil species of *Murraya*, based on leaflets. There is, however, a doubtful record of *Murraya* sp.(?) from the Lower Karewa beds of Kashmir by Puri (1948, p. 118) without any description or illustration. *Murraya paniculata* is a large shrub or small evergreen tree, distributed from the Ravi eastwards to Assam; usually common in the underwood in ravines and forests, throughout the hotter parts of India, Burma, the Andamans and Ceylon. It is also found in China, Australia and the Pacific islands.

FAMILY — LEGUMINOSAE

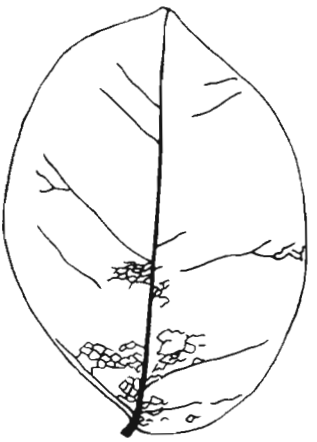
Genus — *Millettia* Wight & Arn.

Millettia asymmetrica Lakhanpal & Guleria

Pl. 10, figs 4-6; Text-fig. 10

1982 *Millettia asymmetrica* Lakhanpal & Guleria, pl. 1, figs 4-6; text-fig. 2.

Description (from Lakhanpal & Guleria, 1982) — Leaflets asymmetrical, elliptic-wide elliptic; lamina length 3.0-3.9 cm, maximum width 1.6-2.7 cm; apex shortly acuminate?; base asymmetrical; margin entire; texture



TEXT-FIG. 10 — *Millettia asymmetrica*, leaf. Natural size.

appearing somewhat coriaceous; petiolule short, 0.1 cm in length; venation pinnate, eucamptodromous, poorly preserved; primary vein (1°) single, size moderate, slightly curved; secondary veins (2°) angle of divergence acute, 60°-50°, thickness fine, curved; smaller veins forming fine meshes; pattern random to orthogonal reticulate; areoles well-developed, shape appearing to be quadrangular; veinlets not seen.

Holotype — B.S.I.P. specimen no. 35418.

Paratype — B.S.I.P. specimen nos. 35419 and 35420.

Occurrence — Khari Nadi Bed (near Goyela-Mokra).

Comparison and discussion — The leaflets of *Dalbergia sissoo* Roxb., *D. latifolia* Roxb., *Pongamia pinnata* (Linn.) Pierre (Syn. *P. glabra* Vent.) and *Millettia ovalifolia* Kurz of the family Leguminosae show near resemblance with the fossil. The leaflets of both the species of *Dalbergia* are broadly elliptic-orbiculate-ovate. Further, the apex of *D. sissoo* leaflet is relatively long acuminate. *Pongamia pinnata* leaflets show better resemblance with the fossil but they differ in having relatively acute angle of secondaries. The fossil shows nearest similarity with the leaflets of *Millettia ovalifolia* in shape, size, form and petiolule length. Besides *M. asymmetrica*, four species of *Millettia* based on the fossil leaflets are known. They are *M. impressa* Menzel (1920) from West Africa, *M. notoensis* Ishida (1970) and *Millettia* sp. Huzioka & Takahasi (1970) from Japan and *M. miocenica*

Lakhanpal & Guleria (1982) from India. Since *M. impressa* is without its description and photograph it is not possible to compare it with the present fossil. The remaining three species differ from the present fossil in form, shape and size. *M. notoensis* is ovate in form and more or less symmetrical in shape; *Millettia* sp. is lanceolate in form and 7.0 cm long; *M. miocenica* is symmetrical in shape and oblong in form as compared to *M. asymmetrica* which is asymmetrical and elliptic—wide elliptic in form and 3.1-3.9 cm long. Thus the present fossil is distinct from the known fossil species of *Millettia* leaflets.

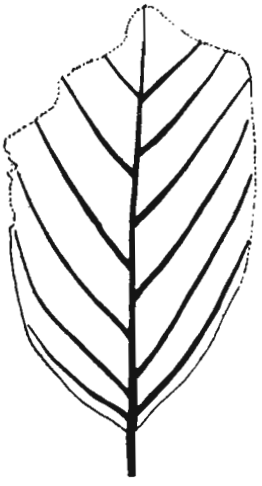
Millettia ovalifolia whose leaflets show resemblance with the fossil, is a tree species found in dry forests of Burma (Brandis, 1906, pp. 220, 706).

Millettia miocenica Lakhanpal & Guleria

Pl. 10, fig. 9; Text-fig. 11

1982 *Millettia miocenica* Lakhanpal & Guleria, 1982, p. 282, pl. 1, fig. 9; text-fig. 3.

Description (from Lakhanpal & Guleria, 1982) — Leaflet symmetrical, seemingly oblong; lamina length 5.6 cm, maximum width 3.2 cm; apex broken; base acute, normal; margin entire; texture chartaceous; petiolule short, 0.6 cm in length; venation pinnate, seemingly eucamptodromous; primary vein (1°) single, stout, slightly curved, unbranched; secondary veins (2°) — angle of divergence acute, moderate, 45°-50°, lowest pair more acute than pairs above, arrangement alternate, number of preserved secondaries six on either side of the midrib, relatively less thick than the primary vein, uniformly curved, unbranched; intersecondary veins absent; tertiary veins (3°) and higher order venation not preserved.



TEXT-FIG. 11 — *Millettia miocenica*, leaf. Natural size.

Holotype — B.S.I.P. specimen no. 35421.

Occurrence — Khari Nadi Bed (near Goyela-Mokra).

Comparison and discussion — The characters exhibited by the fossil can be seen in the leaflets of the species of *Desmodium* Desv., *Millettia* Wight & Arn. and *Pterocarpus* Linn. of the family Leguminosae. The frequency of secondary veins is more in those species of *Desmodium* and *Pterocarpus* which otherwise resemble the present fossil. *Pterocarpus* spp. further differ in having intersecondaries which are absent in the present fossil. Of the various species of *Millettia*, the leaflets of *M. auriculata* Baker, *M. macrostachya* Coll. & Hensl. and *M. pachycarpa* Benth. show resemblance with the fossil. *M. pachycarpa* distinctly differs from *M. miocenica* in the angle of divergence of the lowermost secondaries, which is more acute in the fossil as compared to *M. pachycarpa*. The leaflets of *M. auriculata* and *M. macrostachya* show very close similarity with the fossil and it is difficult to distinguish them merely on the morphological basis. Keeping in view the present day distribution of these two species it is believed that the fossil shows closer affinities with *M. auriculata* than with *M. macrostachya*.

In addition to the present species the authors are aware of 4 species of *Millettia*, viz., *M. impressa*, *M. notoensis*, *Millettia* sp. and *M. asymmetrica* (see p. 249). *M. impressa* cannot be compared with the present fossil for lack of its description and photograph. The remaining species can easily be differentiated from the present fossil on the basis of their shape alone. *Millettia notoensis* is ovate; *Millettia* sp. is lanceolate and *M. asymmetrica* is elliptic-wide elliptic as compared to the present species which is oblong in shape. Thus, the present species differs from all the known fossil species of leaflets of *Millettia*.

Millettia auriculata, a woody climber is found in sub-himalayan tract from the Sutlej eastward, Bihar, Central India, south of Godavary, common in sal forests (Brandis, 1906, p. 219). It is also common in the deciduous forests of Upper and Lower Burma. *M. macrostachya*, a tree species is found in the southern Shan Hills (Burma).

Genus — *Bauhinia* Linn.

Bauhinia kachchhensis Lakhanpal & Guleria

Pl. 11, figs 1, 2, 4; Text-fig. 12

1982 *Bauhinia kachchhensis* Lakhanpal & Guleria, p. 283, pl. 2, figs 10, 12, 13; text-fig. 4.

Description (from Lakhanpal & Guleria, 1982) — Leaf appearing symmetrical, composed of two wide obovate lobes; lamina length 5.0 cm, maximum width 4.0 cm; lobes rounded; apex not preserved; base? cordate; margin entire; texture appearing to be thick chartaceous; petiole not preserved; venation acrodromous; primary vein (1°) four to six in one half, arranged as series of veins of relatively equal thickness, weak, markedly curved; secondary veins (2°) numerous between the two primaries and joining the adjacent primaries, fine curved to wavy; tertiary veins (3°) pattern random to reticulate, distant to closely arranged; areoles well-developed, arrangement oriented, triangular to pentagonal, size medium, veinlets not seen.

Holotype — B.S.I.P. specimen no. 35422.

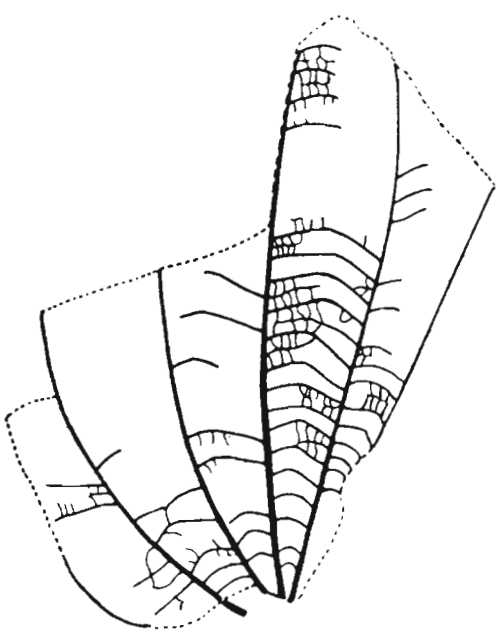
Paratype — B.S.I.P. specimen nos. 35423-35425.

Occurrence — Khari Nadi Bed (near Goyela-Mokra).

Comparison and discussion — The most characteristic feature of the fossil is the acrodromous venation with entire margin of leaf. The specimen is either a folded leaf or just one half of the leaf as indicated by one of the margins of the fossil leaf running almost straight like an edge whereas the other side of the margin is showing clear curvature. This most probably indicates that the fossil leaf has got folded up from the side of the sharp straight edge. Such folding further indicates that the leaf must have had an emarginate apex, as the leaves normally do not get folded up unless the apex is emarginate or the leaf is incompletely or completely bilobed. This kind of leaves having emarginate apex or incompletely to completely lobed lamina with entire margin and acrodromous venation are found in *Bauhinia* Linn. Leaves of a large number of *Bauhinia* species were compared with the fossil. Among them, *Bauhinia purpurea* Linn. and *B. phoenicea* Heyne show very close similarity with the fossil and it is difficult to differentiate the leaves of these two species on the basis of leaf morphology alone.

In addition to the present species, Lakhanpal and Awasthi (1984) have reported the occurrence of a *Bauhinia* leaf, viz., *B. siwalika* from the West Champaran District of Bihar. *B. siwalika* differs from the present species in its smaller size (1.5-4.0 cm in length and 1.0-3.0 cm in width) and in having lesser number of primaries (3-4). Similarly *B. kachchhensis* also differs from the known fossil species of *Bauhinia* leaves from abroad (Lakhanpal & Guleria, 1982, pp. 284, 285).

Of the two comparable species, *B. phoenicea* is a gigantic climber and *B. purpurea* is a medium-sized tree. The former is



TEXT-FIG. 12 — *Bauhinia kachchhensis*, leaf. Natural size.

common in the South Kanara, Wynaad and also found in the evergreen forests of Coorg and Travancore. The latter is found in sub-himalayan tract from the Indus eastwards ascending to 1,600 m in Assam, Khasi Hills, Chittagong, western Peninsula, in deciduous forests.

Genus—*Cassia* Linn.

Cassia miokachchhensis Lakhanpal & Guleria

Pl. 11, fig. 3; Text-fig. 13

1982 *Cassia miokachchhensis* Lakhanpal & Guleria, p. 285, pl. 2, fig. 11; text-fig. 5

Description (from Lakhanpal & Guleria, 1982) — Leaflet almost symmetrical, ovate; lamina length 3.5 cm, maximum width 2.6 cm; apex broken; base obtuse; margin entire; texture seemingly chartaceous; attachment of petiolule normal, petiolule 2.0 cm long; venation pinnate, eucamptodromous; primary vein (1°) simple, stout, slightly curved; secondary veins (2°) — angle of divergence acute (70°-50°), 70° near the base and gradually decreasing upwards, thickness fine, curved upwards, appears unbranched; intersecondaries present, simple; tertiary veins (3°) still finer, pattern random reticulate, simple, distant to close; quaternaries forming fine net work, course orthogonal to randomly oriented; areoles well-developed, oriented, shape appears quadrangular, size small; veinlets not seen.

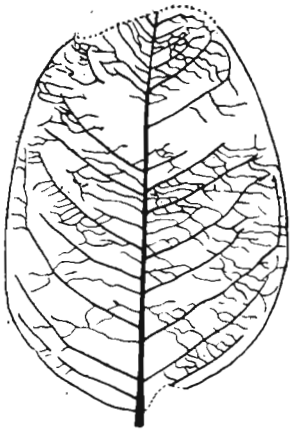
Holotype — B.S.I.P. specimen no. 35426.

Paratype — B.S.I.P. specimen nos. 35427 and 35428.

Occurrence — Khari Nadi Bed (near Goyela-Mokra).

Comparison and discussion — The leaflets of *Cassia* Linn., *Dalbergia* Linn.f., and *Pterocarpus* Linn. of the family Leguminosae show similar characters as exhibited by the present fossil. The leaflets of *Pterocarpus* spp. which show apparent similarity, differ from the fossil in the angle of divergence of secondaries. Among the large number of *Dalbergia* species examined, the leaflets of *D. latifolia* Roxb. and *D. sissoo* Roxb. show close resemblance with the fossil. However, they differ in having broadly elliptic-orbiculate-ovate form. They also differ in texture. The *Cassia* leaflets show best resemblance with *Cassia miokachchhensis* which is the first record of leaflet of *Cassia* from India.

Cassia is a large genus of herbs-shrubs and trees comprising over 500 species of which 24 grow in India (Santapau & Henry, 1973, p. 33).



TEXT-FIG. 13 — *Cassia miokachchhensis*, leaf. Natural size.

Genus — *Leguminocarpon* Goeppert, 1855

Leguminocarpon khariensis Lakhanpal & Guleria

Pl. 12, figs 1-3, 5

1982 *Leguminocarpon khariensis* Lakhanpal & Guleria, p. 286, pl. 3, figs 16-18, 20

Description (from Lakhanpal & Guleria, 1982) — Pods fragmentary; dehiscent; 1.6-7.0 cm long, 1.4-2.5 cm broad, terminating into a short pointed apex; margin wavy due to shallow constrictions setting apart lobes; each lobe containing a single somewhat rounded seed; suture lines visible close to the margins; texture coriaceous.

Holotype — B.S.I.P. specimen no. 35429.

Paratype — B.S.I.P. specimen nos. 35430, 35431, 35432 and 35433.

Occurrence — Khari Nadi Bed (near Goyela-Mokra).

Comparison and discussion — The pods clearly indicate that they belong to the family Leguminosae. As it is difficult to determine the affinity of these pods below

family level, they are placed under the artificial genus *Leguminocarpon* Göeppert (1855) which is the earliest instituted genus for the fossil fruits belonging to the family Leguminosae.

Genus — *Leguminosites* Bowerbank, 1840

Leguminosites khariensis Lakhanpal & Guleria

Pl. 12, figs 4, 6

1982 *Leguminosites khariensis* Lakhanpal & Guleria, p. 286, pl. 3, figs 19, 21

Description (from Lakhanpal & Guleria, 1982) — The species is based on two leguminous seeds. One of them is split open into two parts. Both the specimens are round to circular in form, 1.0-1.9 cm in diameter.

Holotype — B.S.I.P. specimen no. 35434.

Paratype — B.S.I.P. specimen no. 35435.

Occurrence — Khari Nadi Bed (near Goyela-Mokra).

Comparison and discussion — As these seeds have been found in close association with leguminous leaflets and pods they are also considered to be leguminous. Hence they are placed under the artificial genus *Leguminosites* Bowerbank (1840) which represents the fossil seeds belonging to Leguminosae.

Genus — *Leguminophyllum* Lemoigne, Beauchamp & Samuel, 1974

Leguminophyllum khariensis Lakhanpal & Guleria

Pl. 11, fig. 5; Pl. 12, fig. 7; Text-fig. 14

1982 *Leguminophyllum khariensis* Lakhanpal & Guleria, p. 287, pls 2, 3; figs 14, 22; text-fig. 6.

Description (from Lakhanpal & Guleria, 1982) — Leaflets asymmetrical, oblong to narrow ovate; 1.3-1.8 cm long, 0.6 cm wide; apex appearing obtuse to mucronate; base oblique; margin entire; texture chartaceous; petiolule absent; venation pinnate; primary vein (1°) single, stout, slightly curved, ubranched; secondary veins (2°) preserved only in the basal region, angle of divergence acute, 50°, fine, curving upwards; tertiary veins and higher order venation not clear.

TEXT-FIG. 14 — *Leguminophyllum khariensis*, leaf. Natural size.

Holotype — B.S.I.P. specimen no. 35436.

Paratypes — B.S.I.P. specimen nos. 35437 and 35438.

Occurrence — Khari Nadi Bed (near Goyela-Mokra).

Comparison and discussion — The asymmetric shape, small size and the absence of petiole or petiolule indicate that the fossil specimens are the leaflets of a pinnate leaf. The leguminous pods found in close association with these leaflets provide support to the fact that these are the leaflets of a leguminous plant. As the affinity of these leaflets could not be traced beyond family level, they are placed under the artificial genus *Leguminophyllum* Lemoigne *et al.* (1974) which would include all the fossil leaflets of legumes whose exact affinities cannot be found out.

It is likely that *Leguminocarpon khariensis*, *Leguminosites khariensis* and *Leguminophyllum khariensis* may belong to one and the same plant as the leaflets, pods and seeds are preserved in close association though not in actual organic connection.

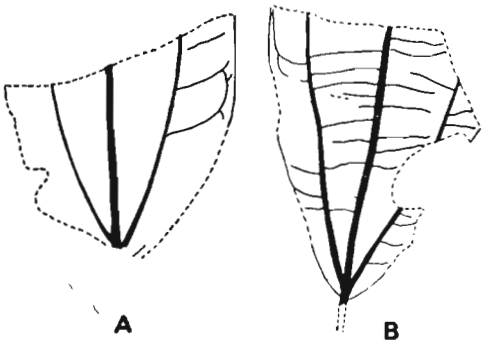
FAMILY — RHIZOPHORACEAE

Genus — *Ceriops* Arnott

Ceriops kachchhensis sp. nov.

Pl. 13, figs 3, 4

This species is based on a single well-preserved specimen which is split into two counterparts.



TEXT-FIG. 15A, B — *Cinnamomum miokachchhensis*, leaves. Natural size.

Description — Leaf slightly asymmetrical, obovate, lamina length 2.6 cm, maximum width 1.6 cm, apex obtuse, base asymmetrical, seemingly acute; margin entire; texture coriaceous; petiole seemingly woody, 2 mm thick, 2.4 cm long; venation pinnate, primary vein (1°) single, almost straight; secondary veins (2°) very faint, only 2-3 secondaries visible in the middle and lower part of leaf, angle of divergence about 50°, tertiaries and higher order venation not preserved.

Holotype — B.S.I.P. specimen no. 35761.

Occurrence — Khari Nadi Bed (near Goyela-Mokra).

Comparison and discussion — The important characters of the fossil are: slightly asymmetrical shape; obovate form; entire margin; seemingly acute base; coriaceous texture; pinnate venation; and long thick woody petiole. In all the above characters the fossil shows close resemblance with the leaves of *Ceriops* Arnott belonging to family Rhizophoraceae. The genus consists of two species, viz., *C. tagal* (Perr.) C.B. Rob. (= *C. candolleana* Arnott) and *C. decandra* (Griff.) Ding Hou (= *C. roxburghiana* Arnott) and both are found on the Indian shores. The fossil was compared with the leaves of both these species and it was found that the fossil shows close similarity with the leaves of both the species in size, shape, texture, etc. However, it is difficult to ascertain as to leaves of which of the two *Ceriops* spp. show best resemblance with the fossil due to poor preservation of veins in the fossil.

As no fossil leaf of *Ceriops* is known so far and because it is difficult to differentiate as to which of the two living species of *Ceriops* it belongs, therefore, the fossil is assigned to a new species *Ceriops kachchhensis* sp. nov.

Of the two comparable species, *Ceriops tagal* occurs in the tidal forests of Sind, the west coast, Sunderbans and the Andamans whereas *C. decandra* is found in the tidal forests of the east coast, Sunderbans, Chittagong and Tenasserim in Burma.

FAMILY — COMBRETACEAE

Genus — *Terminalia* Linn.

Terminalia kachchhensis sp. nov.

Pl. 13, figs 1, 2

The species is based on a single well-preserved specimen representing the lower and middle part of the leaf.

Description — Leaf appearing symmetrical, seemingly elliptic-oblong, preserved lamina length 8.0 cm, maximum preserved width 6.0 cm, maximum width on either side of the midrib varies from 2.9-3.2 cm; apex not preserved; base rounded(?), margin entire, slightly wavy; texture seemingly chartaceous; venation pinnate, eucamptodromous; primary vein (1°) stout, more or less straight; secondary veins (2°) moderately thick, alternately arranged, angle of divergence varies from 80° in the lower region to 55° in upper portion, more or less uniformly curved, upturned near the margin; intersecondary veins not seen; tertiary veins (3°) fine, angle of origin RR to RA, pattern percurrent, branched to unbranched, obliquely arranged in relation to mid-vein, alternate to opposite, closely spaced; quaternary veins (4°) relatively randomly oriented; areoles more or less well-developed, rounded, angular to polygonal in shape; veinlets not seen.

Holotype — B.S.I.P. specimen no. 35762.

Occurrence — Khari Nadi Bed (near Goyela-Mokra).

Comparison and discussion — The fossil shows resemblance in all its characters with the leaves of *Terminalia* Linn. of the family Combretaceae. Leaves of a number of species of *Terminalia* were compared with the present fossil. The fossil shows best resemblance with the leaves of *T. chebula* Retz.

The only known species of *Terminalia* based on fossil leaf from India is *T. panandhroensis* from the Eocene of Panandhro lignite mine, Kachchh (see p. 236). Lately Tripathi and Tiwari (1983) described a leaf-impression of *Terminalia* sp. cf. *T. arjuna* from the Lower Siwalik beds of Nepal about 5 km from the Indian border north of Jarwa in district Gonda, Uttar Pradesh. *T. panandhroensis* is much bigger in size (11.5×9.5 cm) as compared to the present fossil (8.0×6.0 cm) and also differs slightly in the angle of divergence. Secondaries in *T. panandhroensis* appear to run along the midrib for a short distance before diverging out whereas in the present fossil they emerge directly from the mid-vein. The present fossil further differs in having quaternary veins which are absent in *T. panandhroensis*. *Terminalia* sp. of Tripathi and Tiwari can easily be differentiated from the present fossil. In *Terminalia* sp. the base is acute, angle of divergence less than 70° and it is narrow elliptic in form as compared to the present fossil whose base is seemingly rounded, the angle of divergence up to 80° and elliptic-oblong in form. It will not be out of place to mention here that the leaves of *Terminalia arjuna* with which the *Terminalia* sp. has been compared by Tripathi and Tiwari possess rounded or cordate base and generally crenate-serrate margin mainly in the apical part of the leaf (Brandis, 1906, p. 311, fig. 136; Parkinson, 1937, p. 12). In contrast, the *Terminalia* sp. has acute base and nothing can be said about the crenate margin as its apical part is not preserved. In the light of these facts the *Terminalia* sp. needs reinvestigation to establish its correct affinities with the modern species.

As the present fossil is different from the known fossil leaves of *Terminalia* it is assigned to a new species, *Terminalia kachchhensis*. The specific name indicates the area from where the material was collected.

Terminalia chebula is a moderate-sized to large deciduous tree and is found in mixed deciduous forests extending to comparatively dry types throughout India and Burma. It ascends to 1,500 m in the outer Himalayas from the Sutlej eastwards and up to 900 m on dry slopes in the Western Ghats. It is common in both peninsulas and also occurs in Sri Lanka.

FAMILY — LAURACEAE

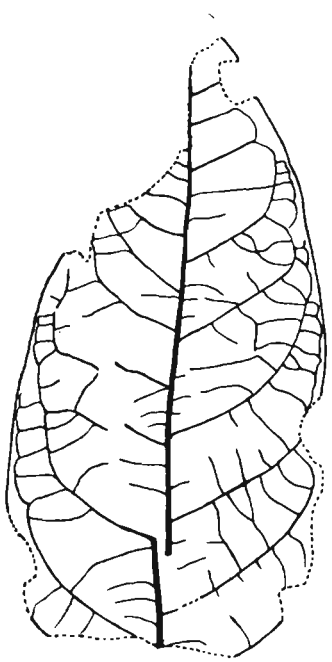
Genus — *Cinnamomum* Schaeffer

Cinnamomum miokachchhensis Lakhanpal & Guleria

Pl. 10, figs 3, 7, 8; Text-fig. 15A, B

1982 *Cinnamomum miokachchhensis* Lakhanpal & Guleria, p. 287, pl. 2, figs 10, 12, 13.

Description (from Lakhanpal & Guleria, 1982) Leaves appearing symmetrical, elliptic to narrow-ovate; preserved lamina length 4.25-6.75 cm, maximum width 2.7-3.5 cm; apex broken, base acute to sometimes obtuse, margin entire; texture seemingly chartaceous; petiole unpreserved; venation basal acrodromous, (?)perfect; primary veins (1°) three, moderate to stout, more or less straight, two lateral primaries slightly curved, unbranched; secondaries (2°) very fine, running approximately at right angles (forming ripples) to acute angles, sometimes branched, emerging from the median primary and joining the two laterals, also arising from the outer side of the two lateral



TEXT-FIG. 16 — *Ficus khariensis*, leaf. Natural size.

primaries at acute angles moving upward and forming fine intramarginal veins, prominent secondaries (seen in specimen nos. 35440 & 35441) moving upwards at acute angles; tertiaries still finer forming numerous fine meshes; areoles imperfect; veinlets not seen.

Holotype — B.S.I.P. specimen no. 35439.

Paratypes — B.S.I.P. specimen nos. 35440 and 35441.

Occurrence — Khari Nadi Bed (near Goyela-Mokra).

Comparison and discussion — The important features of the fossil are: symmetrical shape; elliptic to narrow ovate form; entire margin; basal acrodromous venation; three primaries; and fine secondaries forming intramarginal veins. All these characters can be seen collectively in the leaves of *Cinnamomum*. The present fossil is most likely a variant of *Cinnamomum zeylanicum* Breyn.

In addition to the present species four more species of *Cinnamomum* based on their leaves are known from India (see p. 240). Out of the five, only four species now stand (see p. 240). The presence of intramarginal veins and the absence of prominent secondaries at the basal region differentiate the present fossil from the *Cinnamomum* sp. described by Pathak (1969). In *C. palaeotamala* Lakhanpal & Awasthi (1984) lateral primaries are suprabasal in origin in contrast to their basal origin in the present species. The presence of intramarginal vein further differs it from *C. palaeotamala*. Likewise *C. eokachchhensis* Lakhanpal & Guleria (1981) differs from the present fossil in its bigger size, coriaceous texture, obtuse to almost round base and in the absence of prominent secondaries. Thus *C. khariensis* differs from all the known Indian species of *Cinnamomum*.

Cinnamomum zeylanicum is a large tree and is found in the Western Ghats and adjoining hill ranges, from Konkan southwards and also in Tenasserim (Brandis, 1906, p. 533).

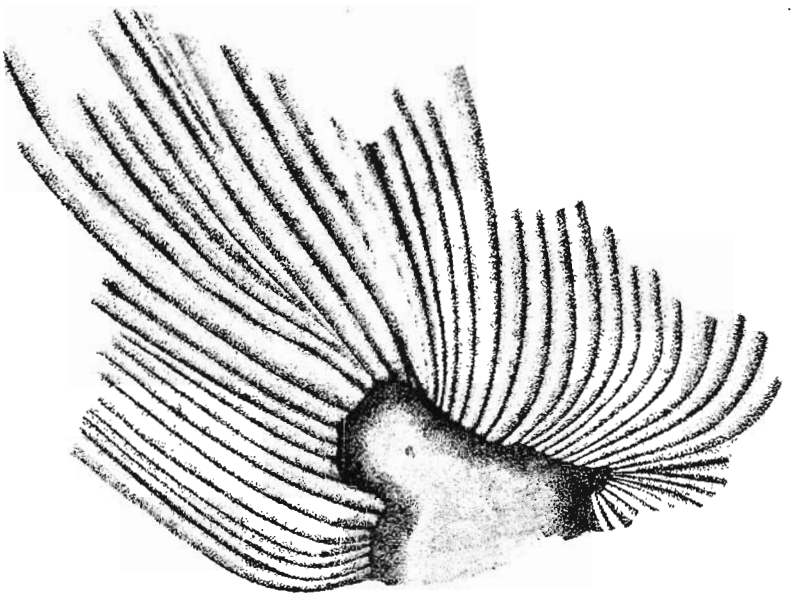
FAMILY — MORACEAE

Genus — *Ficus* Linn.

Ficus khariensis Lakhanpal & Guleria

Pl. 11, fig. 6; Text-fig. 16

1982 *Ficus khariensis* Lakhanpal & Guleria, p. 288, pl. 2, fig. 15; text-fig. 8.



TEXT-FIG. 17 — *Palmacites khariensis*, leaf. Natural size (see page 257).

Description (from Lakhanpal & Guleria, 1982) — Leaf symmetrical, narrow ovate to lanceolate; preserved lamina length 7.7 cm, maximum width 4.1 cm; apex not preserved; base unpreserved (however appearing to be symmetrical); margin entire, slightly wavy; texture seemingly thick chartaceous; petiole unpreserved; venation pinnate, brochidodromous; primary vein (1°) single, stout, slightly curved, secondary veins (2°) angle of divergence acute (75°-60°), 75° near the basal region and gradually decreasing upwards, moderately thick, curved, branched, forming loops near the margin, loop forming branches joining superadjacent secondary at wide acute angle, intersecondary veins present, simple; tertiary veins (3°) angle of origin usually RR to OR, pattern percurrent to reticulate, sometimes joining primary, mostly obliquely arranged in relation to midvein, arrangement seems alternate, distant to close, forming arches just inside the margin enclosing loops formed by secondaries; higher order venation not seen; areoles and veinlets not preserved.

Holotype — B.S.I.P. specimen no. 35442.

Occurrence — Khari Nadi Bed (near Goyela-Mokra).

Comparison and discussion — The above characters of the fossil indicate that it belongs to the genus *Ficus*. The leaves of *Ficus infectoria* Roxb. show apparent similarity with the present fossil.

Among the fossil leaves of *Ficus* known from India (see p. 241) only *Ficus annottiana* Miq. and *F. glomerata* Roxb. described by Mahajan and Mahabale (1973) show some resemblance with the present fossil. The former is bigger in size and the angle of divergence in it is less than 60° as compared to the present fossil in which the angle of divergence varies from 60°-75°. In the latter secondaries bifurcate close to the margin at an angle of 30° and less in contrast to the present species where the corresponding angle is greater than 30°. *Ficus khariensis*, therefore, differs from the known Indian fossil leaves of *Ficus*.

Ficus infectoria with which the fossil show resemblance is found in sub-Himalayan tract and outer hills up to 1,600 m, common in northern India, the Central Provinces, Berar and the western Peninsula (Brandis, 1906, p. 602).

FAMILY — PALMAE

Genus — *Palmacites* Brongniart, 1822

Palmacites khariensis Lakhanpal & Guleria

Pl. 12, fig. 8; Text-fig. 17

1982 *Palmacites khariensis* Lakhanpal & Guleria, p. 290, pl. 3, fig. 23; text-fig. 9.

Description (from Lakhanpal & Guleria, 1982) — Preserved lamina length 9.0 cm, maximum preserved width 9.0 cm; form palmate; petiole thick, broad, incomplete, preserved length 2.5 cm, distal end irregularly rounded with impression of a shallow ridged hastula, costa not seen; lamina consisting of a large number of plicate segments, about 45 preserved, width of segments fused (the specimen consisting of basal region of the leaf), each segment with a midrib in the middle; further details indistinct.

Holotype — B.S.I.P. specimen no. 35443.

Occurrence — Khari Nadi Bed (near Goyela-Mokra).

Comparison and discussion — The palmate form of the fossil and the presence of hastula indicate that it belongs to a true palmate palm (Tomlinson, 1961, p. 24). The true palmate leaves are found only in two sub-families of the family Palmae, i.e. Coryphoideae and Lepidocaryoideae (Corner, 1966, pp. 347, 349, 351). In Lepidocaryoideae there are only three palmate genera, viz., *Mauritia* L.f., *Mauritiella* Burrett and *Lepidocaryum* Mart., the rest being pinnate. The three genera are, however, confined to America (Corner, 1966, p. 349).

Among the five palmate Coryphoid genera found in India (Brandis, 1906, p. 644) only two, *Licuala* Thunb. and *Trachycarpus* H. Wendl. possess true palmate leaves. Both the genera are represented by two species each in India, the former by *Licuala peltata* Roxb. and *L. spinosa* Wurmb. and the latter by *Trachycarpus martiana* Wendl. and *T. takil* Becc. (Blatter, 1926). The leaves of the above referred species of *Licuala* and *Trachycarpus* are much bigger in size. Thus the leaves of none of the modern Indian palms show similarity with the present fossil.

In addition to *Palmacites khariensis*, there are seven records of fossil fan-palm leaves from India. These are: (i) a fan-palm reported by Sahni and Bhatnagar (1962) from the Eocene(?) of Kargil, (ii) *Sabalites microphylla*, (iii) *Sabalites* sp. described by Sahni (1964) from the Miocene beds of Himachal Pradesh and Kashmir, respectively, (iv) *Palmophyllum* sp. Chaudhri (1969) from the Lower Miocene of Kasauli, (v) a palmate leaf described by Trivedi and Chandra (1971) from the Deccan Intertrappean beds of Madhya Pradesh, (vi) *Livistona wadiai* Lakhanpal *et al.* (1983) from the Hemis Conglomerate Horizon (Late Eocene-Oligocene) of Ladakh, and (vii) *Trachycarpus ladakhensis* Lakhanpal *et al.* (1984) from the Liyan Formation (Miocene) of Ladakh. Among these, the fossil shows some resemblance with *Sabalites microphylla*, *Trachycarpus ladakhensis* and *Livistona wadiai*. *Sabalites microphylla*, however, differs in its small size (3.0×2.5 cm) as compared to the bigger size (9.0×9.0 cm) of the *Palmacites khariensis*. *Trachycarpus ladakhensis* differs in having relatively bigger lamina (10.5-19.0 × 14.6 cm) and lesser number of segments. *Livistona wadiai* differs from the fossil in being costa palmate. Thus the present fossil is different from all the known Indian species of palmate leaves.

Family — Lythraceae

Genus — *Lagerstroemioxylon* Mädler, 1939

Lagerstroemioxylon eoflosreginum Prakash & Tripathi

Pl. 25, figs 1-3; Pl. 26, figs 1-2, 4-5

1970 *Lagerstroemioxylon eoflosreginum* Prakash & Tripathi, p. 25, pl. 3, figs 13-15, 17; text-figs 10-13.

The present species is based on two small pieces of secondary wood measuring 11-12 cm in length and 6-7 cm in width. The preservation is fairly good.

Description (based on Kachchh specimen) — *Wood* semi-ring porous (Pl. 25, figs 1-3). *Growth rings* present, delimited by larger vessels at the beginning of ring which grade rather abruptly into smaller vessels in the outer portion of the ring and by denser fibre cells near the outer margin of the ring (Pl. 25, figs 1-3). *Vessels* very small to large in size, round to oval in shape, 6-19 per sq mm, large vessels forming tangential rows at the beginning of early wood (Pl. 25, figs 1-3), solitary, filled with gummy contents and tyloses (Pl. 25, figs 2, 3); late wood vessels smaller in size, usually solitary or in radial multiples of 2-4, open or mostly filled with gummy contents, t.d. 20-225 μm, r.d. 20-135 μm; vessel-members 225-750 μm in length with truncate or tailed ends; perforations simple, nearly horizontal to oblique; intervessel pits could not be observed due to heavy occlusion of vessels either with gummy material or tylosis. *Parenchyma* paratracheal as well as apotracheal; paratracheal fairly abundant, vasicentric, aliform, confluent, sometimes forming small forked or continuous bands up to 12 cells wide at the inception of growth rings; apotracheal parenchyma sparse, cells usually solitary or in small groups scattered in the fibrous tract (Pl. 25, fig. 3); parenchyma cells thin-walled, round, oval to polygonal in shape in cross-section, t.d. 9-24 μm, r.d. 12-24 μm. *Xylem rays* fine, almost all uniseriate, rarely biseriate due to pairing of cells (Pl. 26, figs 1, 2), 6-23 cells or 100-440 μm high, closely spaced, 20-35 per mm; rays homocellular (Pl. 26, fig. 4), consisting of procumbent cells, rarely one or two squarish or upright cells present in some rays; tangential height of procumbent cells 14-24 μm, radial length 40-60 μm; tangential height of squarish or upright cells 28-60 μm, radial length 20-28 μm; crystals present in rays cells. *Fibres* aligned in radial rows in between two consecutive rays, oval to polygonal in cross-section, 5-16 μm in diameter, wall 4-6 μm thick, septate; crystalliferous strands present, divided into several chambers containing solitary crystals (Pl. 26, fig. 5); interfibre pits not seen.

Kachchh specimen — B.S.I.P. specimen nos. 35763 and 35764.

Occurrence — Naiya Dhun.

Comparison and discussion — In all the above mentioned characters the fossil shows close resemblance with the modern woods of *Lagerstroemia* Linn. of the family Lythra-

ceae (Metcalfe & Chalk, 1950; Pearson & Brown, 1932; Kribs, 1959; Purkayastha, 1982). Four Indian species of *Lagerstroemia*, viz., *L. hypoleuca* Kurz, *L. microcarpa* Wight, *L. parviflora* Roxb. and *L. speciosa* Presl. and a number of other species, from abroad, viz., *L. calyculata* Kurz, *L. colleti* Craib, *L. floribunda* Jack., *L. gilletii* Wildem, *L. ovalifolia* Teysen ex Binn; *L. priniformis* Koehnne, *L. subcostata* Koehnne, *L. tomentosa* Presl., *L. venusta* Wall., and *L. villosa* Wall. were examined from their thin sections, photographs and published literature (Kanehira, 1924; Lecomte, 1926; Chowdhury, 1932, 1945; Pearson & Brown, 1932; Metcalfe & Chalk, 1950; Desch, 1957; Brazier & Franklin, 1961; Kribs, 1959; Moll & Janssonius, 1914; Henderson, 1953) in order to find out the closest modern ally of the fossil. It was found that the fossil shows closest resemblance with *L. speciosa* (syn. *L. flos-reginae* Retz.) in almost all its characters (including the rare occurrence of squarish or upright cells in some xylem rays).

Mädler (1939) instituted the genus *Lagerstroemioxylon* for the fossil woods of *Lagerstroemia*. Seven species of *Lagerstroemioxylon* are known, viz., *L. durum* Mädler (1939) from the Pliocene of Frankfurt, West Germany; *L. eoflosreginum* Prakash & Tripathi (1970) from the Tipam sandstones of Assam and from the Tertiary of Sumatra, south-east Asia (Kramer, 1974); *L. parenchymatosum* Prakash (1965, 1973) and *L. irrawaddiensis* Prakash & Bande (1980) from the Tertiary of Burma; *L. arcotense* Awasthi (1981) from the Cuddalore Series near Pondicherry, South India; *L. deomaliensis* Lakhanpal *et al.* (1981) from the Mio-Pliocene beds of Arunachal Pradesh and *Lagerstroemioxylon* sp. Kramer (1974) from the Upper Tertiary of Sumatra. Among these the fossil shows closest resemblance with *Lagerstroemioxylon eoflosreginum*.

Lagerstroemia speciosa is a medium-sized to large deciduous tree. In India it is found throughout Assam, Bengal, western and southern India from North Kanara through Malabar to Travancore; in the Godavari Basin and Kurnool division of Andhra Pradesh. It also occurs in Bangla Desh, Burma, Malay Peninsula and Java. This species is found typically on river banks, low lying places and in similar habitats.

FAMILY — SONNERATIACEAE

Genus — *Sonneratioxylon* Hofmann, 1952

*Sonneratioxylon preapetalum** Awasthi

Pl. 26, fig. 6; Pl. 27, figs 1-5

1969 *Sonneratioxylon preapetalum* Awasthi, p. 254, pls 1-2, figs 1-10; text-figs 1-3.

The present species is based on a single specimen of secondary wood measuring 10 × 3.5 cm in length and width. The preservation is fairly satisfactory.

Description (based on Kachchh specimen) — *Wood* diffuse-porous. *Growth ring* present, usually inconspicuous, delimited by somewhat denser fibrous tissue in the outer portion of ring. *Vessels* very small to small, rarely medium, usually solitary or in multiples of 2-4 (Pl. 27, fig. 1), more or less evenly distributed (Pl. 26, fig. 6), 18-32 per sq mm, round to oval, those in radial multiples flattened at the places of contact, open or sometimes plugged with dark gummy contents and tyloses (Pl. 27, figs 2, 4), t.d. 45-120 μm (mostly 60-75 μm), r.d. 35-80 μm, wall thickness 4-6 μm; vessel-members 120-320 μm in length with truncate or slightly oblique ends; perforations simple; intervessel pits alternate, bordered, vestured, 3-6 μm in diameter, round to oval or elliptical in shape with oval to linear aperture. *Parenchyma* absent. *Xylem rays* fine, almost all uniseriate (Pl. 27, fig. 2), at one place biseriate due to pairing of cells, 12-20 μm wide, 1-18 cells or 36-400 μm in height, closely placed, 20-30 per mm; ray tissue heterogeneous; rays homocellular to heterocellular, consisting of procumbent cells with upright or squarish cells (Pl. 27, fig. 3), upright cells 32-48 μm in tangential height, procumbent cells 16-24 μm in tangential height, radial length could not be measured, solitary crystals occasionally seen in the cells, usually filled with gummy contents. *Fibres* aligned in radial rows between two consecutive xylem rays, more or less oval, angular or polygonal in cross-section, t.d. 8-20 μm, r.d. 12-24 μm, non-libriform, septate (Pl. 27, fig. 5), somewhat

*Awasthi named it as *Sonneratioxylon preapetala*. The specific name has been amended from *preapetala* to *preapetalum* by Kramer (1974) according to International Code of Botanical Nomenclature.

thin-walled, wall 4-6 μm thick; interfibre pits could not be seen.

Kachchh specimen — B.S.I.P. specimen no. 35765.

Occurrence — Naiya Dhun.

Comparison and discussion — The important characters exhibited by the fossil are: *wood* diffuse-porous, vessels very small to medium-sized, solitary or in multiples of 2-4, 18-32 per sq mm; tyloses present; intervessel pits vestured; parenchyma absent; xylem rays almost all uniseriate, heterogeneous, fibres non-libriform, septate.

In all these characters the fossil shows closest similarity with the modern woods of *Sonneratia* Linn. (Metcalfe & Chalk, 1950; Pearson & Brown, 1932; Purkayastha, 1982) of the family Sonneratiaceae. Thin sections of the available modern species of *Sonneratia*, viz., *S. alba* J. Smith, *S. apetala* Buck-Ham, *S. caseolaris* (Linn.) Engler (syn. *S. acida* Linn.) and *S. griffithii* Kurz were examined and it was found that *S. apetala* and *S. caseolaris* show the closest resemblance with the fossil.

Hofmann in 1952 created an organ genus *Sonneratioxylon* to accommodate the fossil woods of *Sonneratia*. Six species of *Sonneratioxylon* are known at present. They are *Sonneratioxylon prambachense* from the Oligocene of Austria, *S. dakshinense* Ramanujam (1957) from the Tertiary of South India, *S. dudukurense* Krishna Rao & Ramanujam (1966) from the Deccan Intertrappean Series at Dudukur (Rajahmundry), Andhra Pradesh, *S. preapetalum* Awasthi (1969) from the Cuddalore Series of South India, *S. intertrappeum* Biradar & Mahabale (1975) from the Deccan Intertrappean Series, Mohgaon Kalan, Madhya Pradesh, *S. caseolarioides** Shete & Kulkarni (1982) and *S. nawargaoensis* Bande & Prakash (1984), both the latter from Nawargaon in Wardha District, Maharashtra. In addition, fossil woods referable to *Sonneratia* have also been described by Verma (1950) and Shallom (1963) from the Deccan Intertrappean beds of Chhindwara District, Madhya Pradesh. However, Biradar and Mahabale (1975, p. 217) merged the woods described by these two authors into *S. intertrappeum*. Further, Chitaley (1969) described the fossil roots comparable to *Sonneratia apetala* as *Sonneratiorhizos raoi*. Out of all these the present fossil shows closest similarity with *Sonneratioxylon preapetalum* in almost all its characters except some slight variations in the size of vessels and rays and in the vessel frequency. Hence the present fossil has been placed under *S. preapetalum*. This species has further been reported from the Tertiary beds of Sumatra and Java by Kramer (1974).

The genus *Sonneratia* consists of five species (Willis, 1973, p. 1078), growing in the mangrove swamps along sea coasts of East Africa, North Madagascar, Seychelles, South-East Asia and warmer regions of Australia. *S. apetala* and *S. caseolaris*, the two comparable species, grow in tidal creeks and littoral forests of India. *S. apetala* is a small to moderate-sized evergreen tree found in delta forests of Bengal, especially common in Sunderbans, in similar localities at the mouth of Godavari, Krishna and Coleroon rivers in Tamil Nadu, and along the creek and backwaters of Thane District in Bombay. It grows in mangrove swamps and very rarely in estuaries also. *S. caseolaris* is a fairly large tree found in Sunderbans, coastal forests of Karnataka and Maharashtra, extending to Indus Delta and in the Andamans. It inhabits estuaries but can also grow in fresh water localities occasionally inundated by sea water.

*Shete & Kulkarni (1982) spelt the species as *Sonneratioxylon caeseolarioides* which should be *S. caseolarioides* vide Article no. 73 of the International Code of Botanical Nomenclature.

PLIOCENE MEGAFOSSILS

I. GYMNOSPERMS

FAMILY — PODOCARPACEAE

Genus — *Podocarpoxylon* Gothan, 1905

Podocarpoxylon kutchensis Lakhanpal, Guleria & Awasthi

Pl. 14, figs 1-6

1975 *Podocarpoxylon kutchensis* Lakhanpal, Guleria & Awasthi, p. 172, pl. 1, figs 1-6; text-figs 1-3.

Description (from Lakhanpal, Guleria & Awasthi, 1975) — *Growth rings* discernible but not conspicuous, wall thickness of tracheids hardly changes from early to late

wood (Pl. 14, figs 1, 2). *Tracheids* of early wood zone occupying greater portion of wood and consisting of 31-62 cells (Pl. 14, figs 1, 2), thin-walled, polygonal with wide lumen, having radial diameter 37-67 μm and tangential diameter 22-45 μm; late wood tracheids forming a narrow zone of 2-4 cells having relatively thick-wall, radial diameter 30-60 μm and tangential diameter 22-45 μm; cells flattened to elliptical, 360-500 cells per sq mm, tangential walls smooth; crystals rarely present. *Parenchyma* seen in cross section as small cells filled with dark contents, thin-walled, end walls as well as tangential walls smooth. *Rays* fine, predominantly uniseriate, rarely biseriate, homocellular (Pl. 14, fig. 3), 1-41 cells or 45-1350 μm in height, usual height 5-18 cells, cell wall thin and smooth. *Pitting* seen on radial as well as tangential walls of tracheids; pits on radial walls mostly in one row, rarely in two, in the latter case opposite or sub-opposite due to lateral compression, solitary or contiguous, oval, circular and bordered, 12-20 μm in diameter, aperture 4-8 μm (Pl. 14, figs 5, 6); rarely uniseriate pits present on tangential walls of tracheids, solitary, 8-16 μm in diameter, pit aperture 4-6 μm in diameter. *Field pits* 1-2, small, circular, oval, simple as well as bordered, podocarpoid to taxodioid (Pl. 1, fig. 4), vertically as well as horizontally arranged, 8-12 μm in diameter, pit aperture up to 4 μm (Pl. 14, fig. 4).

Holotype—B.S.I.P. specimen no. 35199/1336.

Occurrence — Dhaneti.

Comparison and discussion — Considering all the characters mentioned above, the fossil wood shows affinities with Podocarpaceae. The various podocarpaceous genera can be distinguished on the basis of absence or presence of xylem parenchyma and the height of xylem rays. Xylem parenchyma is absent in *Phyllocladus* and *Sciadopitys*. In the remaining genera the xylem rays are less than 25 cells high excepting *Podocarpus* in which the rays are up to 60 cells in height. Due to the presence of xylem parenchyma and xylem ray being 41 cells in height, the fossil wood is clearly assignable to the genus *Podocarpus*.

Of all the modern species of *Podocarpus*, *P. wallichianus* shows the closest resemblance with the fossil wood except that the rays are exclusively uniseriate in *P. wallichianus* whereas they are sometimes biseriate in the fossil.

After a critical examination of podocarpaceous fossil woods, Kräusel (1949) concluded that they should be kept under three genera: *Podocarpoxylon* Gothan, *Phyllocladoxylon* Gothan and *Circoporoxylon* Kräusel. Since the Kachchh fossil shows closest affinity with the *Podocarpus* wood, it has been assigned to the fossil genus *Podocarpoxylon*.

Five species of podocarpaceous woods have so far been described from the Tertiary of India, all from the Cuddalore Sandstones. They are (i) *Podocarpoxylon* (*Mesembrioxylon*) *schmidianum* Kräusel (1949), (ii) *Mesembrioxylon sahnii* Ramanujam (1953), (iii) *M. tiruvakkarianum* Ramanujam (1953), (iv) *M. speciosum* Ramanujam (1954) and (v) *M. mahabalei* Agashe (1969). Except *Podocarpoxylon schmidianum*, the other four species are quite different from the present fossil (see Lakhanpal *et al.*, 1975, p. 175). In *P. schmidianum* the rays are longer (2-100 cells) than in the Kachchh fossil. Further the solitary pits present on the tangential walls of the tracheids of the Kachchh specimen have not been observed in *P. schmidianum*. Thus *Podocarpoxylon kutchensis* is distinct from the rest of the podocarpaceous woods described from the Tertiary of India.

Podocarpus wallichianus with which *Podocarpoxylon kutchensis* resembles is a large evergreen tree occurring in Tinnevely Ghats, South India, ascending from 1,000-1,500 m, Khasi Hills at 1,000 m, tropical forests of the hills of Martaban and Tenasserim in Burma, Malayan Peninsula and Java.

ANGIOSPERMS

FAMILY — DIPTEROCARPACEAE

Genus — *Dipterocarpoxylon* Holden emend. Den Berger, 1927

Dipterocarpoxylon malavii Ghosh & Ghosh, 1959

Pl. 15, figs 1-4

1959 *Dipterocarpoxylon malavii* Ghosh & Ghosh, p. 328, figs 1-3

1983 *Dipterocarpoxylon malavii* Ghosh & Ghosh: Guleria, p. 109, pl. 1, figs 1-4

Description (from Guleria, 1983) — *Wood* diffuse-porous. *Growth rings* absent. *Vessels* small to large, mostly medium, exclusively solitary, evenly distributed (Pl. 15, fig. 1), 5-7 per sq mm; tangential diameter 80-240 μm (average 150 μm), radial diameter 112-350 μm, thin-walled, vessel-members 180-440 μm with truncated ends; perforations simple; pits leading to contiguous tracheids arranged in vertical rows, 4-6 μm in diameter, bordered, vestured; tyloses abundant, sometimes completely plugging the vessels (Pl. 15, fig. 2). *Vasicentric tracheids* sparse, intermingled with paratracheal parenchyma, round the vessels. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma sparse, intermingled with vasicentric tracheids, forming 1-2 cells wide sheath around vessels, sometimes aliform; apotracheal parenchyma diffuse to diffuse-in-aggregate and also associated with vertical gum canals (Pl. 15, fig. 2), frequently extending laterally uniting with those of neighbouring gum canals forming 3-8 (mostly 3-4) cells thick bands; cells circular to oval, elliptic to polygonal in cross section, 8-36 μm in diameter. *Rays* fine to moderately broad, 1-7 seriate (frequently 3-5), about 6-8 per mm: ray tissue heterogeneous; uniseriate ray homocellular to heterocellular, consisting of upright as well as both upright and procumbent cells, 3-13 cells or 30-400 μm high, 16-32 μm wide; multiseriate ray heterocellular, consisting of procumbent cells in the median portion and 1-several upright cells forming uniseriate extension at one or both the ends (Pl. 1, fig. 4), 10-60 cells or 120-1600 μm in height, up to 208 μm wide; sheath cells frequently present; upright cells 32-60 μm in tangential height, 22-40 μm in radial length; procumbent cells 4-20 μm in tangential height, 40-60 μm in radial length. *Fibres* aligned in radial rows between two consecutive rays, cells circular to polygonal in cross section, 4-12 μm in diameter, non-septate, thick-walled, wall thickness 4-6 μm; pits about 4 μm in diameter, arranged in single row, bordered, vestured. *Gum canals* frequent, vertical, diffuse, mostly solitary or in pairs, forming short groups up to 4 enclosed together by parenchyma (Pl. 15, figs 1, 2), rarely 5, about 3-4 per sq mm, circular to oval, tangential diameter 40-120 μm, radial diameter 40-140 μm.

Specimen — B.S.I.P. specimen no. 36003.

Occurrence—Dhaneti, Vinjhan & Sandhan.

Comparison and discussion — The above anatomical details clearly indicate that the fossil is very similar to the wood of *Dipterocarpus*. Of the woods of various *Dipterocarpus* species compared, that of *D. dyeri* is the only one which possesses all the xylotomical details exhibited by *Dipterocarpoxylon malavii*. *Dipterocarpus dyeri* now occurs in the tropical evergreen forests of Burma, Indochina and Malay Peninsula (Chowdhury & Ghosh, 1958, p. 115).

Besides *D. malavii*, there are 24 species of *Dipterocarpoxylon* known so far from the Neogene deposits of East Africa, India, Burma, Java and Sumatra.

2. *Dipterocarpoxylon pondicherriense* Awasthi

Pl. 15, fig. 5; Pl. 16, fig. 1

1974 *Dipterocarpoxylon pondicherriense* Awasthi, p. 339, pl. 1, figs 1, 3; pl. 2, figs 5, 6.

1983 *Dipterocarpoxylon pondicherriense* Awasthi: Guleria, p. 111, pl. 1, fig. 5; pl. 2, fig. 8.

Description (from Guleria, 1983)— *Wood* diffuse-porous. *Growth rings* absent. *Vessels* small to large, mostly medium, exclusively solitary (Pl. 15, fig. 5), evenly distributed, t.d. 96-240 μm (average 160 μm), r.d. 160-360 μm, 6-7 vessels per sq mm; tyloses not clearly seen, gummy material occasionally filled in the vessels; vessel-members 240-440 μm in length with truncated ends; perforations simple; pits leading to contiguous tracheids arranged in vertical rows, 4-6 μm in diameter, vestured. *Vasicentric tracheids* sparse, intermingled with paratracheal parenchyma, forming narrow sheath round the vessels; tracheidal cells oval or slightly flattened, 16-40 μm in diameter. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma relatively sparse, forming narrow sheath round the vessels; apotracheal parenchyma associated with vertical gum canals (Pl. 15, fig. 5), frequently extending sideways uniting with those of neighbouring gum canals and forming short bands of 3-6 cells in thickness; diffuse cells occasionally present; cells oval to polygonal in cross section, 15-28 μm in diameter. *Rays* fine to moderately broad, 1-6 (mostly 4-5) seriate (Pl. 16, fig. 1), 12-75 cells or 325-1920 μm high, up to 120 μm wide

5-7 per mm; ray tissue heterogeneous; uniseriate rays homocellular to heterocellular, consisting of upright cells as well as both upright and procumbent cells, 3-12 cells or 128-320 μm high, 20-28 μm wide; multiseriate rays heterocellular, consisting of procumbent cells through the median portion and 1-several upright cells forming uniseriate extension at one or both the ends (Pl. 16, fig. 1); sheath cells occasionally present (Pl. 16, fig. 1). *Fibres* aligned in radial rows in cross section, oval to polygonal, 8-16 μm in diameter, nonseptate, thick-walled, wall thickness 4-6 μm, pits bordered, 4 μm in diameter. *Gum canals* abundant, vertical, diffuse, enclosed by parenchyma, occasionally solitary, sometimes in pairs and usually in tangential rows of 4-7 per sq mm (Pl. 15, fig. 5).

Kachchh specimen — B.S.I.P. specimen no. 36004.

Occurrence — Mothala and Vinjhan.

Comparison and discussion — The vertical gum canals characteristic of this wood too occur mostly in short tangential rows consisting up to 11 ducts enclosed by apotracheal parenchyma. Further, the paratracheal parenchyma is scanty, forming usually narrow incomplete sheath around vessels. In these features together with all other anatomical details, the fossil shows closest resemblance with the wood of *Dipterocarpus indicus*. In all other species of *Dipterocarpus*, the number of vertical gum ducts aligned together forming short tangential rows is always less than in the Kachchh fossil wood as well as in *Dipterocarpus indicus*. Considering the size, frequency and distribution pattern of gum canals of *D. pondicherriense* it can be easily differentiated from all the other known species of *Dipterocarpoxylon*.

Dipterocarpus indicus Bedd. is a lofty tree up to 40 m high, distributed in evergreen forests of western ghats from North Kanara southwards, Malabar and Travancore. It is common in South Kanara at the foot-hills and at an elevation up to 900 m especially in South Travancore.

FAMILY — STERCULIACEAE

Genus — *Pterospermoxylon* Awasthi, Guleria & Lakhanpal, 1980

Pterospermoxylon kutchensis Awasthi, Guleria & Lakhanpal

Pl. 17, figs 1-3, 5-7; Pl. 18, figs 1, 3

1980 *Pterospermoxylon kutchensis* Awasthi, Guleria & Lakhanpal, p. 199, pl. 1, figs 1-4; pl. 2, figs 6, 8-10; text-fig. 1A-C.

Description (from Awasthi, Guleria & Lakhanpal, 1980) — *Wood* diffuse porous. *Growth rings* present, irregular in contour, delimited by denser and darker late wood fibres (Pl. 17, figs 1, 2). *Vessels* solitary or in radial multiples of 2-3, rarely 5-6 (Pl. 17, figs 2, 3), small to medium, oval to elliptical in cross section, t.d. 56-132 μm (average 100 μm), r.d. 88-240 μm (average 180 μm), wall about 4 μm in thickness, evenly distributed, about 6-10 vessels per sq mm; vessel-members 300-450 μm in height (average 330 μm) with horizotal or slightly obliquely placed end walls; perforations simple; intervessel pits 4-6 μm in diameter, alternate, bordered, polygonal, with linear apertures; tyloses present, mostly thick-walled, pitted (Pl. 17, fig. 5) with characteristic flat walls across at right to the vessel wall forming chambers, vessels sometimes containing dark contents. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma scanty, only a few cells associated with vessels; apotracheal parenchyma diffuse or in uniseriate lines, forming fine reticulum with rays (Pl. 17, figs 2, 3), strands sometimes showing tendency towards storied arrangements; cells circular or oval to elliptical in cross section, 12-28 μm in diameter, 50-80 μm in height. *Rays* fine to medium in width, 1-5 (mostly 2) seriate (Pl. 17, fig. 5; Pl. 18, figs 1, 3), 12-70 μm in width, 8-70 cells or 140-1,320 μm in height, 10-12 per mm, closely placed; ray tissue heterogeneous; rays heterocellular, consisting of mostly procumbent cells and a few tile-cells of *Pterospermum* type (Pl. 17, fig. 6; Pl. 18, figs 1, 3), sheath cells rarely seen; low upright cells rectangular in tangential section, thin-walled, 32-44 μm in vertical height and 20-24 μm in radial length; procumbent cells circular to oval in tangential section, thick-walled, 12-16 μm in vertical height, 40-100 μm in radial length. *Fibres* arranged in radial rows between two consecutive rays, oval, angular to polygonal in cross section, 6-12 μm in diameter, thick-walled with narrow lumen, common walls about 4-8 μm thick, nonseptate, interfibre pits not seen. *Ripple marks* seen at places.

Holotype — B.S.I.P. specimen no. 35316.
Occurrence — Mothala.

Comparison and discussion — The most important and one of the diagnostic features of the fossil is the presence of tile-cells in the rays. Tile-cells have been defined by Chattaway (1933) as special type of erect cells without visible contents occurring in radial series, much narrower radially than the procumbent cells of the ray and interspersed among them. They are of two types, *Durio*-type and *Pterospermum*-type. In the Kachchh specimen the tile-cells are of *Pterospermum*-type in which the rays in tangential section are seen consisting of large angular cells (tile-cells) devoid of any contents, interspersed with clusters of small cells containing dark contents (procumbent cells) more clearly seen in the radial section, where the procumbent cells are usually about half as high vertically as the tile-cells and about four to six times as long. Besides tile-cells, in all other anatomical characters also the fossil wood is very similar to the wood of *Pterospermum*. Out of more than a dozen species of *Pterospermum* available for comparison, *P. glaberescens* W. & A., *P. reticulatum* W. & A. and *P. rubiginosum* Heyne show closest resemblance with the fossil. There is no other known record of *Pterospermum* as fossil wood.

The genus *Pterospermum* Schreb. consists of 40 species (Willis, 1973, p. 963) widely distributed in the tropical forests of south-east Asia, the Andamans, Java, Borneo and Philippines. The above three species with which the fossil resembles most are known to have been distributed in Western Ghats.

Genus — *Sterculinium* Guleria, 1983

Sterculinium kalagarhense (Trivedi & Ahuja) Guleria

Pl. 16, figs 2-5

1978 *Sterculioxylon kalagarhense* Trivedi & Ahuja, p. 24, figs 1-3.
1983 *Sterculinium kalagarhense* (Trivedi & Ahuja) Guleria, p. 112, pl. 2, figs 6, 7, 9, 10; text-fig. 1.

Description (from Guleria, 1983) — *Wood* diffuse-porous (Pl. 16, fig. 2). *Growth rings* not clearly seen, however, delimited by somewhat denser and narrower late wood fibres. *Vessels* solitary or in radial multiples of 2, rarely 3-4, medium to large, mostly oval or flattened due to compression, t.d. 132-286 μm (average 250 μm), r.d. 118-308 μm, wall 4-13 μm thick, evenly distributed, about 1-2 vessels per sq mm; vessel-members 200-400 μm in height with horizontal to slightly oblique ends; perforations simple; intervessel pits medium, hexagonal or polygonal in outline, 4-8 μm in diameter, crowded, alternate, bordered, aperture round or elliptical to linear (Pl. 16, fig. 5); tyloses not seen; vessels often filled with dark contents. *Parenchyma* abundant, both paratracheal and apotracheal; paratracheal sparse; forming narrow sheath of 1-3 cells round the vessels; apotracheal parenchyma forming regular tangential bands, about 4-6 bands per mm, each 4-7 cells wide (Pl. 16, fig. 3), about four cells per strand, thin-walled, 20-30 μm in diameter, 40-90 μm in height, crystals present; strands storied. *Rays* of two sizes, broad and narrow (Pl. 16, fig. 4); narrow rays few, 1-4 (mostly 1-2) seriate or 20-60 μm broad, short, 5-14 cells or 100-400 μm in height, homocellular to heterocellular, consisting of upright and procumbent cells; broad rays mostly spindle-shaped, up to 25 seriate or 560 μm broad and 25-90 cells or 800-3420 μm (average 1280 μm) in height, cells in the median portion of broad rays sometimes disorganised; ray tissue heterogeneous; rays heterocellular, consisting of upright cells at one or both the ends and procumbent cells in the median portion; sheath cells present, upright cells 24-44 μm in vertical height; procumbent cells variable in shape, 8-20 μm in vertical height. *Fibres* poorly preserved, zonate, in broad conspicuous alternating bands, almost as broad as parenchyma bands (Pl. 16, figs 2, 3); cells rectangular to polygonal in cross section, 12-20 μm in diameter, non-libriform to libriform, thin to thick-walled, wall 3-6 μm thick, non-septate; interfibre pits not seen. *Gum canals* present at some places, aligned in regular tangential rows (Pl. 16, fig. 2), about 1-2 rows per cm, 208-400 μm in radial diameter, tangential diameter variable due to flattening.

Kachchh specimen — B.S.I.P. no. 36005.
Occurrence — Dhaneti and Naliya.

Comparison and discussion — The fossil shows affinity in all its xylotomical characters with those species of *Sterculia* which

have regular parenchyma bands alternating with fibre bands of almost same width. Among such sterculias the fossil is comparable to *Sterculia appendiculata* K. Schum ex Engl., *S. blancoi* Rolfe, *S. blumi* G. Don, *S. cinerea* A. Rich, *S. coccinea* Roxb., *S. elegantiflora* Hutch. & Dalz., *S. oblonga* Mast., *S. pallens* Wall., *S. rhinopetala* K. Schum, *S. guttata* Roxb., *S. populifolia* Roxb. and *S. tragacantha* Lindley. Besides, there are a few more sterculiaceous woods which possess broad parenchyma bands and are closely allied to *Sterculia*, viz., *Erythropsis fulgens* (Wall. ex Mast.) Ridley (=*Sterculia fulgens* Wall.), *Firmiana colorata* (Roxb.), *Pterygota alata* (Roxb.) R. Br. (=*Sterculia alata* Roxb.) and *Scaphium wallichii* Scott & Engl. (=*Sterculia scaphigera* Wall.). All these species show general similarity with the fossil in the nature and distribution of vessels, parenchyma bands and xylem rays. However, considering further details, such as the size and frequency of vessels, width of parenchyma bands, width and height of rays and the presence of concentric rings of vertical traumatic gum canals the fossil wood appears closer to *Sterculia coccinea, S. oblonga* and *S. rhinopetala.*

Of the above three species, *S. coccinea* occurs in the eastern Himalaya ascending up to 900 m in Bhutan, Sikkim and Assam Hills and in Burma extending southwards to Tenasserim (Chowdhury & Ghosh, 1958, p. 214). The remaining two species are confined to tropical forests of Africa.

The genus *Sterculioxylon* was instituted by Kräusel (1939) for the fossil woods resembling *Sterculia* and allied genera of Sterculiaceae. Since then several fossil woods resembling *Sterculia* and allied genera of Sterculiaceae have been described by various workers from the Palaeogene and Neogene sediments of India and abroad (Guleria, 1983, pp. 115-116). Recently one of us (Guleria, 1983) has shown that the genotype of *Sterculioxylon* does not possess the xylotomical character of *Sterculia* and allied genera and therefore he proposed a new generic name, *Sterculinium* to include all the fossils resembling those of *Sterculia* and allied genera. Accordingly he transferred all these fossil woods to *Sterculinium.*

Sterculinium kalagarhense with which the present Kachchh fossil has been identified, was earlier described from the Siwalik beds of Kalagarh, U.P.

FAMILY — SAPINDACEAE

Genus — *Euphorioxylon* Awasthi, Guleria & Lakhanpal, 1982

Euphorioxylon indicum Awasthi, Guleria & Lakhanpal

Pl. 18, figs 4, 5; Pl. 19, figs 1, 2

1982 *Euphorioxylon indicum* Awasthi, Guleria & Lakhanpal, p. 12, pl. 1, figs 1-4.

Description (from Awasthi, Guleria & Lakhanpal, 1982)— *Wood* diffuse-porous. *Growth rings* not seen. *Vessels* small to medium, solitary or in radial multiples of 2-5 (Pl. 18, figs 4, 5), rarely up to 12, t.d. 50-140 μm, r.d. 60-180 μm, thick-walled, common wall 80-20 μm in thickness, evenly distributed, 9-14 per sq mm; vessel-members 120-160 μm in length with truncated ends; perforations simple; intervessel pits small, alternate, bordered, about 4-5 μm in diameter with small, circular aperture; tyloses absent; vessels sometimes filled with dark contents. *Parenchyma* paratracheal, sparse, limited to a few cells, forming at the most narrow or incomplete sheath around the vessels (Pl. 18, fig. 5), cells round to oval in cross section, 20-32 μm in diameter. *Rays* uniseriate (Pl. 19, fig. 1), rarely biseriate mainly due to pairing of cells through the median portion, 12-24 μm wide, 4-60 cells or 60-720 μm high, closely placed, 12-18 per mm; ray tissue homogeneous; rays homocellular, consisting of procumbent cells only (Pl. 19, figs 1, 2), cells round to oval, 10-20 μm in tangential height and 20-160 μm in radial length. *Fibres* aligned in radial rows between two consecutive rays, round to oval in cross section, 12-20 μm in diameter, thick-walled, walls about 3-6 μm, nonseptate to rarely septate.

Kachchh specimen — B.S.I.P. no. 35359.

Occurrence — Dhaneti and Mothala.

Comparison and discussion — Among the dicotyledonous families, the members of Sapindaceae exhibit the above xylotomical characters. Further, considering all the anatomical details collectively, it was found that the fossil shows closest resemblance

with *Euphoria longana* Lamk. (=*Nephelium longana* Camb.).

There are quite a number of fossil woods referred to the family Sapindaceae, known from the Indian Tertiary sediments and abroad (see Awasthi *et al.*, 1982) but none of them is exactly similar to that of *Euphoria*.

The genus *Euphoria* consists of about 15 species (Santapau & Henry, 1973, p. 66) of shrubs and trees, distributed from Burma to Indochina and western Malaysia. *Euphoria longana* Lamk. with which the fossil resembles most is found throughout the Western Ghats from the Konkan southwards extending to Sri Lanka up to 900 m, in the hills of Assam, South China, Burma and Malaya (Anonymous, 1963, p. 225).

Genus —*Schleicheroxylon* Awasthi, Guleria & Lakhanpal, 1982

Schleicheroxylon kutchensis Awasthi, Guleria & Lakhanpal

Pl. 19, figs 3, 4, 6; Pl. 20, figs 1, 3

1982 *Schleicheroxylon kutchensis* Awasthi, Guleria & Lakhanpal, p. 15, pls 1-2, figs 5-13.

Description (from Awasthi, Guleria & Lakhanpal, 1982)— Wood diffuse-porous. *Growth rings* present, delimited by dark zone consisting of dense and thick-walled fibres towards the close of annual increment (Pl. 19, fig. 4). *Vessels* small to medium, solitary and in radial multiple of mostly 2-3 (Pl. 19, figs 3, 4), rarely forming clusters, more or less evenly distributed, 11-14 per sq mm, circular to oval, t.d. 60-152 μm, r.d. 60-200 μm, thick-walled, walls 8-20 μm in thickness; vessel-members 160-500 μm in length with truncated ends; perforations simple; intervessel pits small, alternate, bordered (Pl. 20, fig. 3), about 4 μm in diameter; tyloses absent; vessels filled with dark contents. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma sparse, usually confined to the tangential walls of vessels due to contiguous rays, occasionally forming incomplete to 1-2 celled sheath around vessels (Pl. 19, fig. 3); apotracheal scanty, diffuse cells aggregated towards the inner part of ring not exactly forming lines; cells round to oval in cross section, 12-24 μm in diameter. *Rays* fine, 1-2, rarely 3 seriate (Pl. 20, fig. 1), mostly uniseriate or 12-32 μm wide, 2-30 (mostly 8-16) cells or 40-800 μm high, 11-16 per mm; ray tissue homogeneous, rays homocellular, consisting of procumbent cells (Pl. 19, fig. 6); cells round to oval, 12-24 μm in tangential height, 48-80 μm in radial length, infiltration dark. *Fibres* aligned in radial rows in cross section, round to oval, about 6-12 μm in diameter, walls 3-6 μm in thickness, septa not clearly seen.

Holotype — B.S.I.P. specimen no. 35358.
Occurrence — Dhaneti.

Comparison and discussion — The above mentioned xylotomical details are characteristics of the family Sapindaceae and hence the fossil can be compared with the sapindaceous woods. In having a combination of some important characters such as small to medium-sized, solitary and multiple vessels, scanty paratracheal parenchyma and sometimes diffuse parenchyma cells aligned in undulating tangential rows at regular intervals indicating seasonal growth, 1-2 (occasionally 3) seriate homocellular rays and nonseptate to septate fibres — the fossil shows closest resemblance with the wood of *Schleichera oleosa* (Lour.) Oken and differs from the other genera of the family.

Among the known fossil woods of Sapindaceae, *Sapindoxylon schleicheroides* described by Dayal (1965) from the Deccan Intertrappean beds near Nagpur, shows some resemblance with the Kachchh fossil since it has also been compared with *Schleichera oleosa*. Both the fossils exhibit somewhat similar shape, size and distribution of vessels, scanty paratracheal parenchyma, 1-3 (mostly 1) seriate rays and nonseptate to septate fibres. However, the Kachchh fossil can be distinguished from the Deccan Intertrappean, in having distinct seasonal growth marks delimited by thick-walled narrow fibres and diffuse parenchyma cells, often forming uniseriate lines and rays exclusively homocellular.

The genus *Schleichera* consists of a single species, *S. oleosa* (Lour.) Oken, found in the Indomalayan region (Willis, 1973, p. 1042). In India, it occurs in the Sub-Himalayan tract up to 900 m, from the Sutlej eastward (except perhaps Assam, Bengal and the Andamans), central India and western Peninsula in the deciduous forests.

Genus — *Millettioxylon* Awasthi, 1967

Millettioxylon indicum Awasthi

Pl. 20, figs 4, 5

1967 *Millettioxylon indicum* Awasthi, p. 180, figs 1-3.
1975 *Millettioxylon indicum* Awasthi, p. 47, pl. 1, figs 1, 3, 5-8.
1984 *Millettioxylon indicum* Guleria, p. 247, pl. 2, figs 7, 8.

Description (from Guleria, 1984) — *Wood* diffuse-porous. *Growth rings* not seen. *Vessels* small to large, mostly medium, solitary and in radial multiples of 2-4 (Pl. 20, fig. 4), sometimes forming clusters, evenly distributed, 3-6 vessels per sq mm; circular to oval in cross section, t.d. 64-224 μm, r.d. 80-288 μm; perforations simple; vessel-members 280-460 μm in length with truncated ends, storied with parenchyma strands and rays; intervessel pits alternate, bordered, vestured, about 4 μm in diameter; tyloses not seen, vessels sometimes filled with dark contents. *Parenchyma* in regular concentric bands, alternating with fibre bands of more or less same width or of relatively greater width (Pl. 20, fig. 4), bands slightly undulating, sometimes bifurcating and joining adjacent bands; 4-5 bands per mm; each 3-8 cells wide, parenchyma strands storied, about 4 cells per strand; cells round to oval in cross section, 16-28 μm in diameter. *Xylem rays* fine, 1-3 (mostly 2), very rarely 3 seriate or 8-28 μm wide, 3-20 cells or 80-360 μm high, storied, 11-14 rays per mm; ray tissue homogeneous to weakly heterogeneous; rays homocellular to weakly heterocellular, consisting of procumbent cells and sometimes with a single marginal row of square or upright cells at one or both the ends (Pl. 2, fig. 8); upright or square cells 24-32 μm in vertical height, 36-40 μm in radial length, procumbent cells, 12-20 μm in vertical height, 60-100 μm in radial length. *Fibres* forming concentric bands, alternating with parenchyma bands of more or less same width (Pl. 20, fig. 4), circular, oval to angular in cross section, 8-16 μm in diameter, nonseptate, thick-walled, walls 4-8 μm thick with narrow lumen. *Ripple marks* present due to storied arrangement of vessel members, parenchyma strands and rays.

Kachchh specimen — B.S.I.P. nos. 36028 and 36029.

Occurrence — Dhaneti, Sandhan and Mothala.

Comparison and discussion — In all the above mentioned xylotomical characters the fossil is closely comparable with the modern woods of *Pongamia* and *Millettia*. Further, from critical examination of the sections of woods of these genera it was found that the fossil shows close similarity in all its anatomical features with that of *Pongamia pinnata* (Linn) Pierre Vent., *Millettia pendula* Benth. and *M. prainii* Dunn.

Of the six known species of *Millettioxylon* (see Guleria, 1984, p. 248), the Kachchh fossil is identical with *M. indicum* Awasthi (1967, 1975).

Of the two species of *Millettia* with which the fossil shows resemblance, *M. pendula* is found in the drier forests of Burma, common in Pegu Yoma, Shweba, Upper Chindwin and Tenasserim, and *M. prainii* occurs in the eastern Himalayas in the foot-hills of Sikkim, extending into the plains of North Bengal and also in Assam along the right bank of the river Manas in Goalpara and in the Garo Hills (Ramesh Rao & Purkayastha, 1972, p. 116). The genus *Pongamia* which also shows close resemblance consists of a single species, viz., *P. pinnata*, a medium-sized tree, occurring throughout the greater part of India and Burma, chiefly along streams and rivers, being common in the tidal and beach forests and very common in the Andamans. It is also found in Sri Lanka and Malaya extending to North Australia and China (Ramesh Rao & Purkayastha, 1972, p. 122).

Genus — *Pahudioxylon* Chowdhury, Ghosh & Kazmi, 1960

Pahudioxylon sahnii Ghosh & Kazmi, 1961

Pl. 21, figs 1, 5

1961 *Pahudioxylon sahnii* Ghosh & Kazmi, p. 96, figs 1, 2.
1984 *Pahudioxylon sahnii* Ghosh & Kazmi: Guleria, p. 240, pl. 1, figs 3, 4.

Description (from Guleria, 1984) — *Wood* diffuse porous. *Growth rings* present, delimited by fine lines of apotracheal parenchyma. *Vessels* small to large, mostly medium, solitary and in radial multiples of 2-4, (Pl. 21, fig. 1), evenly distributed, 4-6

per sq mm, round to oval, t.d. 60-220 μm in height with truncated ends; perforations simple; intervessel pits alternate, oval to slightly elliptical or polygonal, 4-10 μm in diameter, vestured. *Parenchyma* paratracheal, vasicentric, typically aliform, sometimes aliform-confluent (Pl. 21, fig. 1); apotracheal parenchyma represented by narrow lines of 1-3 cells in width, cells round or oval to elliptical in cross section, 16-32 μm in diameter, 80-130 μm in length, thin-walled; crystalliferous strands occasionally present with several locules, each containing solitary crystal. *Rays* fine, 1-3 seriate, mostly 2-seriate (Pl. 21, fig. 3) or 10-48 μm (commonly 20-30 μm) wide, 3-25 cells and 72-380 μm (average 240-280 μm) high, 10-13 rays per mm, showing tendency towards storied arrangement (Pl. 21, fig. 3), homocellular, consisting of procumbent cells. *Fibres* aligned in radial rows, circular or oval to angular in cross section, thick-walled, 8-16 μm in diameter, nonseptate, pits not seen.

Kachchh specimen — Material consumed.

Occurrence — Dhaneti, Kothara, Vinjhan.

Comparison and discussion — The fossil wood, in all its anatomical features, resembles the woods of *Afzelia* and *Intsia*. The genera *Afzelia* (=*Pahudia*) and *Intsia* are xylotomically inseparable, and therefore the fossil woods resembling those are placed under the genus *Pahudioxylon* Chowdhury, Ghosh & Kazmi (1961)

So far 13 species of *Pahudioxylon* are known from several Neogene deposits of India. It should be pointed out here that there is not much difference in the structural details from one species of *Pahudioxylon* to another. If a critical re-examination of the type slides and even the re-assessment of anatomical differences from their description and illustrations is made, the total number of the species of *Pahudioxylon* described so far would be reduced to about half. The Kachchh fossil wood possesses all the anatomical details exhibited by *P. sahnii* Ghosh & Kazmi and differs from all other species in some minor characters.

Pahudioxylon assamicum Prakash & Tripathi

Pl. 21, figs 2, 4

1975 *Pahudioxylon assamicum* Prakash & Tripathi, p. 54, pl. 2, figs 7, 9, 11, 12; text-fig. 2.

1984 *Pahudioxylon assamicum* Prakash & Tripathi: Guleria, p. 241, pl. 2, figs 11, 12.

Description (from Guleria, 1984) — *Wood* diffuse porous. *Growth rings* present, delimited by terminal parenchyma lines, 2-5 per cm (Pl. 21, fig. 2). *Vessels* small to large, mostly medium, solitary or in radial multiples of 2-4, occasionally filled with dark contents, round to oval in cross section, t.d. 64-220 μm, r.d. 70-280 μm, wall about 4 μm thick, vessel-members 160-360 μm in height, usually with truncate ends; perforations simple; intervessel pits alternate, oval to slightly elliptical, 4-8 μm in diameter, vestured. *Parenchyma* paratracheal, vasicentric, mostly aliform, sometimes aliform-confluent; apotracheal parenchyma forming narrow lines of 1-3 cells in thickness (Pl. 21, fig. 2); cells round to oval, 12-24 μm in diameter, 80-160 μm in length, thin-walled, crystalliferous strands occasionally present with several locules containing solitary crystals. *Xylem rays* fine to medium, 1-4 seriate (mostly 3 seriate), rarely 4 seriate or 8-72 μm wide (Pl. 21, fig. 4), 2-30 cells or 66-404 μm (average 15-18 cells or 240-320 μm in height), 5-8 per mm; occasionally showing tendency towards storied arrangement; ray tissue homogeneous, rays homocellular, consisting of procumbent cells (Pl. 21, fig. 4); cells thin-walled, 8-16 μm in vertical height. *Fibres* aligned in radial rows, circular to oval or slightly elliptical in cross section, non-libriform to semi-libriform, 8-22 μm in diameter with wide lumen, nonseptate, interfibre pits not seen.

Kachchh specimen — B.S.I.P. nos. 36020 and 36021.

Occurrence — Dhaneti and Mothala.

The genus *Afzelia* Sm. comprises 14 species distributed in tropical Africa and Asia (Willis, 1973, p. 30). In India only *Afzelia bijuga* A. Gray [*Intsia bijuga* (Colebr.) O. Ktze.] and *A. retusa* Kurz are found. *Afzelia bijuga* occurs in tidal forests of Bengal, the Andaman Islands and Burma while *A. retusa* is found in the coastal forests of Sunderbans and the Andamans (Gamble, 1902). The genus *Intsia* Thou. consists of 9 species found in offshore islands of tropical East Africa, Madagascar and tropical Asia (Willis, 1973, p. 593).

Genus — *Cynometroxylon* Chowdhury & Ghosh, 1946

Cynometroxylon holdeni (Gupta) Prakash & Bande

Pl. 22, figs 1, 2

1980 *Cynometroxylon holdeni* (Gupta) Prakash & Bande, p. 266, pl. 3, figs 11-14.
1984 *Cynometroxylon holdeni* (Gupta) Prakash & Bande: Guleria, p. 242, pl. 2, figs 9, 10.

Description (from Guleria, 1983) — *Wood* diffuse-porous. *Growth rings* discernible but not conspicuous. *Vessels* small to medium, solitary and in radial multiples of 2-5 (mostly 2-3), sometimes forming small clusters, uniformly distributed, 7-9 vessels per sq mm; oval to elliptic in cross section, t.d. 60-140 μm, r.d. 75-180 μm; vessel-members 160-480 μm in height, ending slightly obliquely; perforations simple; intervessel pits small, 4-5 μm in diameter, alternate, bordered, vestured, apertures linear to lenticular; tyloses absent; vessels sometimes filled with dark contents. *Parenchyma* abundant, in regular concentric bands, alternating with fibre bands of more or less same width, undulating, often completely enclosing the vessels, sometimes bands bifurcating and joining adjacent ones, bands 3-9 cells wide, 4-5 per mm (Pl. 22, fig. 1); parenchyma cells circular to oval in cross section, 17-28 μm in diameter and 60-120 μm in height, non-storied. *Xylem rays* 1-4 (mostly 2-3) seriate, 6-43 cells and 120-750 μm, often 13-20 cells and 270-380 μm high, 6-12 rays per mm; ray tissue heterogeneous, rays homocellular to mostly heterocellular, consisting of procumbent cells in the median portion and 1-2 upright or square cells at one or both the ends (Pl. 22, fig. 2); cells upright to squarish and procumbent, vertical height of upright or squarish cells 30-44 μm and radial length 20-40 μm, vertical height of procumbent cells 16-25 μm and radial length 60-100 μm; crystals rarely seen, dark infiltration present. *Fibres* almost of the same width as alternating parenchyma bands (Pl. 22, fig. 1), cells polygonal to angular, 6-20 μm in diameter, libriform, thick-walled with narrow lumen, 4-6 μm thick, nonseptate, pits not seen.

Kachchh specimens — B.S.I.P. nos. 36022, 36023 and 36024.

Occurrence — Dhaneti, Naliya and Mothala.

Comparison and discussion — The above anatomical features of the fossil collectively indicate its close resemblance with the woods of *Cynometra* in general and *Cynometra polyandra* and *C. ramiflora* in particular.

Besides *Cynometroxylon indicum* (Gupta) Bande & Prakash (=*Cynometroxylon indicum* Chowdhury & Ghosh) with which the present Kachchh fossil is identified, there are two more species of *Cynometroxylon*, viz., *C. dakshinense* Navale (1959) described from the Cuddalore Series near Pondicherry and *C. prainaequifolium* Prakash (1979) described from the Tertiary of Thailand. *Cynometroxylon dakshinense* differs from *C. holdenii* in having rays mostly 1-2 seriate with a tendency towards storied arrangement. *C. prainaequifolium* can also be differentiated from the Kachchh fossil in having vessels relatively large to medium-sized (75-180 μm, r.d. 75-300 μm), parenchyma bands 2-5(7) cells thick and rays 1-2 (mostly 2) seriate and up to 40 cells high.

The genus *Cynometra* Linn. consists of 60 species (Willis, 1973, p. 329) of evergreen trees or shrubs, distributed throughout the tropics in the Indo-Malayan region, Philippines, Australia, Pacific islands, Mexico, Brazil and Africa. Six species are known to occur in India. Of the two species with which the Kachchh fossil resembles, *Cynometra polyandra* is a large evergreen tree found in Cachar, Garo, Lushai and Khasi Hills of northeast India, Sylhet and Chittagong in Bangladesh. *C. ramiflora* is a small to medium-sized tree found in the coastal tidal forests of Sunderbans, Western Coast of South India, Andamans and Sri Lanka (Gamble, 1902).

Genus — *Isoberlinioxylon* Lakhanpal & Prakash, 1970

Isoberlinioxylon congoense Lakhanpal & Prakash

Pl. 22, figs 3-6

1970 *Isoberlinioxylon congoense* Lakhanpal & Prakash, p. 10, pl. 6, figs 19-21; pl. 7, figs 22, 24.
1983 *Isoberlinioxylon congoense* Lakhanpal & Prakash: Guleria, p. 243, pl. 3, figs 15-18.

Description (from Guleria, 1983) — *Wood* diffuse-porous. *Growth rings* delimited by narrow lines of parenchyma, smaller vessels and thick-walled fibres (Pl. 22, figs 4, 5). *Vessels* small to large (mostly medium), solitary or in radial multiples of 2-4 (mostly solitary), evenly distributed, 4-6 per sq mm; tyloses not seen; vessels occasionally filled with dark contents (Pl. 22, figs 4, 5), round to oval in cross section, t.d. 75-225 μm (mostly 135-150 μm), r.d. 90-225 μm (mostly 180 μm), walls about 4-6 μm thick, vessel-members 160-480 μm (often 200-220 μm) in height with truncated ends; perforations simple; intervessel pits alternate to sub-opposite, 3-6 μm in diameter, vestured. *Parenchyma* paratracheal and apotracheal, paratracheal parenchyma abundant, vasicentric, aliform (forming prominent halo around vessels with very short tangential extensions) to confluent; apotracheal parenchyma scanty, diffuse, occasionally seen as shining whitish cells and forming narrow lines of 1-2 cells wide delimiting the growth rings (Pl. 22, figs 4, 5); cells round to oval in cross section, 12-40 μm in diameter, 80-200 μm in height, crystalliferous strands occasionally present with single crystal in each locule. *Rays* fine, 1-3 seriate (3-seriate rarely seen), or 10-36 μm wide, 3-28 cells or 50-480 μm (often 200-220 μm) in height, 5-11 per mm; ray tissue homogeneous to weakly heterogeneous; rays homocellular to weakly heterocellular, consisting of procumbent cells and sometimes with a single marginal row of square or upright cells at one or both the ends (Pl. 3, figs 17, 18), upright cells 32-44 μm in vertical height, procumbent cells 8-24 μm in vertical height, radial length could not be measured; cells filled with dark contents. *Fibres* aligned in radial rows, round or oval to polygonal in cross section, 4-16 μm in diameter, thick-walled, walls 4-6 μm thick, probably nonseptate; interfibre pits not seen.

Kachchh specimens — B.S.I.P. nos. 36025 and 36026.

Occurrence — Dhaneti.

Comparison and discussion — The above features of the fossil collectively indicate that it shows close similarity with the woods of an African genus *Isoberlinia* Craib. of the family Leguminosae. Detailed comparison with the thin sections of *Isoberlinia niembaensis* and *I. angolensis* as well as with the published description and illustrations of *Isoberlinia angolensis* (Welw.) Hoyle & Brenan, *I. niembaensis* Duvingn and *I. tomentosa* (Harms) Craib & Staff. (Lebacq, 1957, pls 79-81) has shown that the fossil is very similar to *I. angolensis* and *I. niembaensis*.

There is only one species of fossil woods of *Isoberlinia*, viz., *Isoberlinioxylon congoense* (Lakhanpal & Prakash, 1970) from the Miocene of lake Albert, Congo. The Kachchh fossil specimen is almost identical with this species in all its anatomical features.

The genus *Isoberlinia* Craib & Stapf. consists of six species, confined to tropical Africa (Willis, 1973, p. 598).

Genus — *Dialiumoxylon* Lemoigne, 1978

Dialiumoxylon indicum Guleria

Pl. 23, figs 1, 2

1983 *Dialiumoxylon indicum* Guleria, p. 244, pl. 1, figs 5, 6; pl. 3, fig. 19.

Description (from Guleria, 1983) — *Wood* diffuse-porous. *Growth rings* not seen. *Vessels* small to medium, solitary as well as in radial multiples of 2-5 (mostly 2-4), rarely up to 6 (Pl. 23, fig. 1), uniformly distributed, 9-13 vessels per sq mm; round to oval in cross section, t.d. 50-140 μm (average 80 μm), r.d. 56-160 μm (average 120 μm); perforations simple; vessel-members 160-400 μm in length with truncated ends, storied with parenchyma strands and rays; intervessel pits alternate, bordered, vestured, 4-6 μm in diameter, vessels occasionally filled with dark contents. *Parenchyma* in regular concentric bands, alternating with relatively broad fibre bands (Pl. 23, fig. 1); bands straight to slightly undulating, touching or enclosing the vessels, 4-6 per mm, each 2-5 (mostly 2-4) cells wide, parenchyma strands storied, 4 cells per strand; cells round to oval in cross section, 12-28 μm in diameter, 60-100 μm long, crystalliferous strands present with solitary crystals in each locule. *Rays* fine, 1-3 seriate (mostly biseriate), 16-40 μm wide, 5-17 cells or 120-360 μm in height, storied (Pl. 23, fig. 2), sometimes irregularly storied; 8-11 rays per mm; ray tissue homogeneous;

rays homocellular, consisting of procumbent cells only. *Fibres* forming concentric bands, alternating with relatively narrow parenchyma bands (Pl. 23, fig. 1), cells oval to angular in cross section, 6-10 μm in diameter with narrow lumen, thick-walled, walls about 4 μm thick, nonseptate. *Ripple marks* present, visible due to storied arrangement of vessel-segments, parenchyma strands and rays.

Holotype — B.S.I.P specimen no. 36027.

Occurrence — Dhaneti.

Comparison and discussion — The above xylotomical features clearly indicate that the fossil belongs to the family Leguminosae. Among legumes, the woods of a few genera, such as *Bauhinia*, *Craibia*, *Cynometra*, *Dalbergia*, *Dialium*, *Geoffroea*, *Lonchocarpus*, *Machaerium*, *Millettia*, *Piscidia*, *Pongamia*, *Pterocarpus*, *Schefflerodendron* and *Swartzia* (Metcalfe & Chalk, 1950) are comparable to the present Kachchh fossil. However, taking into consideration all the xylotomical details such as the shape, size and frequency of solitary and multiple vessels, width and frequency of parenchyma bands, height and width of rays, the fossil shows close resemblance with the woods of *Dialium*. Of the large number of *Dialium* species compared, *D. angolense*, *D. gossweilerii*. *D. laurinum*, *D. pentadrum*, *D. travancoricum* and *D. zenkeri* appear to be closer to this fossil.

Dialiumoxylon aethiopicum is the only other known fossil wood of *Dialium* described earlier (Lemoigne *et al.*, 1974) from the Miocene beds of Mush Valley, Ethiopia. The two species differ from one another in some minor characters. In *Dialiumoxylon aethiopicum* the parenchyma bands are in straight concentric bands and the rays are up to 4 (mostly 2-3) seriate and 200-300 μm in height, whereas in *D. indicum* the parenchyma bands are mostly wavy and sometimes anastomosing and the rays are 1-3 (mostly 2) seriate and 120-360 μm in height.

The genus *Dialium* consists of 40 species, found in the tropics of South America, Madagascar and Malaysia (Willis, 1973, p. 352). In India this genus is represented by a single species, *D. travancorium* Bourd. which occurs in the forests of South Travancore between 300 m and 600 m (Ramesh Rao & Purkayastha, 1972, p. 78).

Genus — *Albizinium* Prakash, 1975

Albizinium eolebbekianum Prakash

Pl. 23, figs 3, 4

1975 *Albizinium eolebbekianum* Prakash, p. 197, pl. 3, figs 9, 11, 12.

1983 *Albizinium eolebbekianum* Prakash: Guleria, p. 239, pl. 1, figs 1, 2.

Description (from Guleria, 1983) — *Wood* diffuse-porous. *Growth rings* present delimited by thin lines of apotracheal (terminal) parenchyma (Pl. 23, fig. 3). *Vessels* medium to large (mostly large), mostly solitary or in radial multiples of 2-3, rarely 4, sometimes forming small clusters, evenly distributed, about 3-6 per sq mm, round to oval, t.d. 120-480 μm, walls 4-6 μm in thickness; vessel-members 160-360 μm in height, with truncated ends; perforations simple; intervessel pits oval to elliptical, 4-8 μm in diameter, bordered, alternate, vestured; tyloses not seen; vessels filled with dark contents. *Parenchyma* paratracheal and apotracheal; paratracheal parenchyma vasicentric to aliform with short lateral extensions, sometimes aliform-confluent (Pl. 23, fig. 3); apotracheal represented by thin, 1-3 seriate terminal lines; cells round to elliptical in cross section, thin-walled, t.d. 16-24 μm; crystalliferous strands present containing solitary crystal in each locule. *Rays* 1-5 (mostly 3-4) seriate (Pl. 23, fig. 4) and 12-100 μm in width, 6-9 rays per mm, homocellular, composed of procumbent cells, 3-25 cells and 48-360 μm high; cells 12-32 μm in vertical height, 40-100 μm in radial length; infiltration dark. *Fibres* aligned in radial rows, circular to oval in cross section, 12-20 μm in diameter, wall 4-6 μm in thickness, septate; length 40-100 μm; interfibre pits present, simple, round to oval, 2-4 μm in diameter.

Kachchh specimen — B.S.I.P. nos. 36017 and 36018.

Occurrence — Dhaneti and Mothala.

Comparison and discussion — The above characters collectively indicate that the fossil wood belongs to the genus *Albizia* Durraz., showing close resemblance with *Albizia lebbek* Benth. For naming the fossil woods resembling *Albizia* Prakash (1975) created the genus *Albizinium*. Of the three species of *Albizinium* known so far, namely, *Albizinium eolebbekianum*

Prakash described from various Neogene deposits of India (Prakash, 1975; Prakash & Bande, 1980; Ghosh & Roy, 1982; Lakhanpal *et al.*, 1981), *A. pondicherriense* Awasthi (1979) from the Cuddalore Series near Pondicherry and *A. hungaricum* (Greguss) Guleria (1983) from the Middle Miocene of Hungary, *Albizinium eolebbekianum* is identical with the Kachchh fossil wood. *Albizia lebbek* Benth., with which the Kachchh fossil resembles, is found throughout India, ascending up to 1200 m in the Himalayas and is common in the Andamans (Ramesh Rao & Purkayastha, 1972, p. 36).

Albizinium pondicherriensis Awasthi, 1979

Pl. 23, fig. 5; Pl. 24, fig. 1

1979 *Albizinium pondicherriensis* Awasthi, p. 157, pl. 1, figs 1, 3; pl. 2, figs 5-7.
1984 *Albizinium pondicherriensis* Awasthi; Guleria, p. 240, pl. 1, figs 3, 4.

Description (from Guleria, 1984) — *Wood* diffuse-porous. *Growth rings* delimited by thin lines of parenchyma and thick-walled fibres. *Vessels* small to large, usually medium, mostly solitary or in radial multiples of 2-3, rarely 4 (Pl. 24, fig. 1), sometimes forming small clusters, evenly distributed, about 3-6 vessels per sq mm; round to oval, t.d. 60-260 μm, r.d. 60-320 μm, walls about 4 μm in thickness; vessel-members 120-300 μm in height with truncated ends; perforations simple; intervessel pits round to oval, about 4-6 μm in diameter, bordered, alternate, vestured, tyloses absent; vessels often filled with dark contents. *Parenchyma* mostly aliform to confluent, enclosing 2-3 neighbouring vessels; apotracheal parenchyma represented by thin, 1-2 seriate terminal lines; crystalliferous strands present containing solitary crystal in each chamber. *Rays* fine, 1-2 (rarely 3) seriate (Pl. 23, fig. 5) and 12-32 μm (mostly 20 μm) broad, 10-15 per mm, homocellular, consisting of procumbent cells only, short, about 3-20 cells or 60-360 μm in height; cells thin-walled, 8-16 μm in vertical height, 40-120 μm in radial length, usually filled with dark contents. *Fibres* aligned in radial rows, polygonal in shape, 8-20 μm in diameter, thick-walled, 4-6 μm in thickness, septate, pits not seen.

Kachchh specimen — B.S.I.P. no. 36019.

Occurrence — Dhaneti.

Comparison and discussion — This fossil is very similar to the woods of the genus *Albizia* particularly with *Albizia amara* and *A. odoratissima*. Its resemblance with the former can be seen in the shape, size and frequency of rays while with the latter in the size of the vessels. The fossil wood from Kachchh is identical with *Albizinium pondicherriense* Awasthi (1979) from the Cuddalore Series near Pondicherry.

Albizia amara Boivin is found in dry forests of the Indian Peninsula from Khandesh in the west to Visakhapatanam in the east, extending towards in the west coast in dry forests of Travancore and also in Sri Lanka (Gamble, 1902).

FAMILY — COMBRETACEAE

Genus — *Terminalioxylon* Schönfeld, 1947

Terminalioxylon felixii Ramanujam

Pl. 24, figs 2, 3

1956 *Terminalioxylon felixii* Ramanujam, p. 108, pl. 7, figs 7-11; text-figs 7-12.
1983 *Terminalioxylon felixii* Ramanujam: Guleria, p. 118, pl. 3, figs 11, 12.

Description (from Guleria, 1983) — *Wood* diffuse-porous. *Growth rings* distinct, demarcated by narrow lines of parenchyma and small vessels (Pl. 24, fig. 2). *Vessels* small to large (mostly medium), t.d. 60-230 μm, r.d. 144-340 μm, mostly solitary or in radial multiples of 2-4, evenly distributed, 5-7 vessels per sq mm; vessel-members 120-400 μm in height with truncated ends; perforations simple; tyloses present (Pl. 24, fig. 2); vessels sometimes filled with dark contents; intervessel pits small, alternate, oval to elliptic, about 4 μm in diameter, vestured. *Parenchyma* paratracheal and apotracheal, paratracheal parenchyma vasicentric to aliform (Pl. 24, fig. 2), sometimes confluent when vessels closely placed; apotracheal parenchyma aggregate and forming narrow lines of 1-3 cells wide at the inception of growth rings (Pl. 24, fig. 2); cells oval to slightly elliptic in cross section, 16-28 μm in diameter, thin-walled, crystalliferous strands occasionally present with several chambers containing solitary crystals. *Rays* fine, uniseriate, occasionally with paired cells (Pl. 24, fig. 3),

12-40 μm wide, 5-21 cells or 120-520 μm high; 14-16 rays per mm; ray tissue homogeneous to weakly heterogeneous; rays homocellular to weakly heterocellular, consisting of procumbent cells with single, marginal row of upright or squarish cells at one or both the ends (Pl. 24, fig. 3). *Fibres* aligned in radial rows, oval to polygonal in cross section, 8-16 μm in diameter, thick-walled, wall thickness about 4 μm, noseptate, interfibre pits not seen.

Kachchh specimen — B.S.I.P. no. 36006.

Occurrence — Mothala.

Comparison and discussion — The above mentioned characters collectively indicate that the fossil wood belongs to the genus *Terminalia* Linn. of the family Combretaceae. Of a large number of woods of *Terminalia* spp. examined, *T. arjuna* and *T. tomentosa* are very close to the present fossil.

So far about 35 species of fossil woods resembling *Terminalia* have been described under the genus *Terminalioxylon* Schönfeld from the Tertiary rocks of India and abroad (Guleria, 1978; Guleria, 1983). Lately one more species, *T. ghoshii* has been described by Satyanarayana and Mahabale (1984) from the Pangadi in Andhra Pradesh. Of these *Terminalioxylon felixii* Ramanujam (1956) reported from the Tertiary rocks near Pondicherry is identical with the present fossil, except for minor difference in the frequency of vessels.

Terminalioxylon burmense Mädel-Angeliewa & Müller-Stoll

Pl. 24, figs 4, 5

1968 *Terminalia tomentosa* Prakash & Dayal, p. 233, figs 1, 2.

1983 *Terminalioxylon burmense* Mädel-Angeliewa & Müller-Stoll: Guleria, p. 119, pl. 3, figs 13, 14.

Description (from Guleria, 1983) — *Wood* diffuse-porous. *Growth rings* distinctly marked by narrow lines of parenchyma and small vessels (Pl. 24, fig. 5). *Vessels* small to medium (mostly medium), t.d. 60-200 μm (average 120 μm), r.d. 90-270 μm, mostly solitary or in multiples of 2-4, evenly distributed, 6-10 vessels per sq mm; tyloses present (Pl. 24, fig. 5); vessels occasionally filled with dark contents and crystals; vessel-members 160-448 μm in height with truncated ends; perforations simple; intervessel pits alternate, oval to elliptic, sometimes coalescent, about 2-4 μm in diameter, vestured. *Parenchyma* both paratracheal and apotracheal; paratracheal parenchyma vasicentric to aliform and confluent (mostly aliform); apotracheal parenchyma forming narrow lines indicating the inception of seasonal growth, 1-3 cells wide (Pl. 24, fig. 5); parenchyma cells round, oval to elliptic, 16-28 μm in diameter, thin-walled crystalliferous strands occasionally present with several chambers containing solitary crystals. *Xylem rays* fine, mostly uniseriate (Pl. 24, fig. 4), occasionally with paired cells, 12-28 μm wide, 3-29 (mostly 11-15) cells or 40-480 μm high, 10-14 rays per mm; ray tissue homogeneous to weakly heterogeneous; rays homocellular to weakly heterocellular, consisting of procumbent cells or with single marginal row of upright or squarish cells at one or both the ends (Pl. 24, fig. 4); upright cells 20-28 μm in vertical height, procumbent cells 12-20 μm in vertical height, radial length could not be measured. *Fibres* oval to polygonal in cross section, thick-walled, walls about 4 μm thick, 8-16 μm in diameter, occasionally septate, interfibre pits not seen.

Kachchh specimen — B.S.I.P. no. 36007.

Locality — Dhaneti.

Comparison and discussion — The present fossil also shows close similarity in all its anatomical features with the woods of *Terminalia* in general and *T. tomentosa* in particular. Among the species of *Terminalioxylon* Schönfeld the present Kachchh fossil wood is very similar to *Terminalioxylon burmense* Mädel-Angeliewa & Müller-stoll (1973). This species was created to include all the fossil woods described earlier as *Terminalia tomentosa* W. & A. by Chowdhury and Tandon (1964) from the Tertiary of Burma, Prakash (1966) from the Tertiary of Nagaland and Prakash and Dayal (1968) from Kachchh.

The genus *Terminalia* Linn. consists of about 250 spp. of large trees, widely distributed in the tropical regions of both the hemispheres (Willis, 1973, p. 1136). Of the two species of *Terminalia* with which the Kachchh fossil woods resemble, *T. arjuna* Bedd. is distributed throughout the greater part of India from Avadh (Uttar Pradesh) southwards usually along banks of rivers and streams, ravines and dry water

courses and occurs in southern, western and central India, Bihar, Orissa, part of Maharashtra, Tamil Nadu and in Sri Lanka. *T. tomentosa* is also very common and probably the most widely distributed in all the important forest trees of India. It occurs in the sub-Himalayan regions from Punjab eastwards to Goalpara in Assam.

Family — Palmae

Genus — *Palmoxylon* Schenk, 1882

Palmoxylon kachchhensis Guleria

Pl. 28, figs 1-6

1983 *Palmoxylon kachchhensis* Guleria, p. 120, pl. 3, figs 15, 16; pl. 4, figs 17-21.

Description (from Guleria, 1983) — The material on which this species is based, consists of a single piece measuring 11 cm in length and 6.7 cm in diameter. The cortical, dermal and the central zones are lacking and only the subdermal zone is present as indicated by the spacing and orientation of fibrovascular bundles in the specimen.

Fibrovascular bundles obovate, orbicular, reniform and rarely ovate in shape (Pl. 4, figs 17, 19), usually regularly oriented, fairly distinctly placed without touching the neighbouring bundles, 28-52 (average 40) bundles per sq mm; t.d. 0.75-1.4 (average 1.0) mm; r.d. 1.2-1.5 mm; f/v ratio varies from 5-10/1; sclerenchyma surrounded by 1-2 (3) layers of thin-walled more or less flattened cells of tabular parenchyma (Pl. 4, figs 20, 21); radiating parenchyma also present; dorsal sclerenchyma cap reniform or cordate type, auricular lobes rounded at their ends; ventral sclerenchyma cap not seen; sclerenchyma tissue highly disintegrated and impregnated by silica; the xylem consists of 1-3 (mostly 1-2) vessels, excluded, vessels filled with dark contents, annular thickenings seen in vessels; xylem parenchyma occasionally preserved; phloem between the xylem and median sinus almost disorganised except in a few fibrovascular bundles where it is seen as patch of badly preserved tissue; median sinus generally rounded or angular; stegmata present in the fibrous part of fibrovascular bundles. Leaf-trace bundles present. *Growth parenchyma* consists of oval, polygonal and elongated (mostly elongated) cells, thin-walled, occasionally relatively thick-walled, forming radial plate-like structure (Pl. 28, figs 4-6), almost compact, occasionally small intercellular spaces present, crystals present between the neighbouring fibrovascular bundles in the ground parenchyma. *Fibre bundles* absent.

Kachchh specimen — B.S.I.P. no. 36008.

Occurrence — Mothala.

Comparison and discussion — The fossil shows close similarity with the *Cordata* and *Reniformia* types of palm woods. In fact, to which of these two subgroups the fossil exactly belongs, is difficult to decide due to the absence of dermal and central region in the present fossil. A very large number of *Palmoxylon* spp. are known from India and abroad. A comprehensive list of these has been given by Prakash and Boureau (1968) and Prakash (1974). In addition, a few more species have been described afterwards. From a detailed comparison with all the known species of *Palmoxylon* it was found that the Kachchh fossil palm is quite different, and hence named as *Palmoxylon kachchhensis*.

Megafossils from Unknown Tertiary Horizons

Monocotyledons

Genus — *Culmites* Brongniart, 1822

Culmites cutchensis Sahni

Pl. 29, figs 1-6

1964 *Culmites cutchensis* Sahni, p. 13, pl. 1, figs 9-11.

Description (from Sahni, 1964, p. 13, para 4, given as Diagnosis) — Aerial stem erect, cylindrical, glazed, 1.5 cm thick; internodes.....*long, nodes not enlarged, sheathing leaf-base persisted, parallel-nerved rhizome with shorter internodes (.....long)*.

*Details not given in original MS.

Dormant buds broadly ovate, plano-convex recalling those of *Saccharum*; epidermal cells on aerial stem oblong with sinuous walls, stomata 500-550 per mm².

Comparison and discussion — The specimens, according to Sahni, "almost certainly belong to the Gramineae, but cannot be identified with any particular genus. They are, therefore, assigned to Brongniart's artificial genus *Culmites* which includes stems of monocotyledons whose exact affinities are unknown" (Sahni, 1964, p. 12).

Figured specimens — (i) G.S.I. C176f. mentioned by Sahni but not traceable, (ii) B.S.I.P. no. 35722, (iii) figured as no. 3, reproduced from Sahni, specimen not traceable, and (iv) B.S.I.P. no. 35723.

Occurrence — Exact locality not known, similar glazed cylindrical casts of monocotyledonous stems are recorded by Wynne (1872, p. 18) from north of Kaira Fort. The present specimens may have been found at the same place.

Family — Palmae

Genus — *Palmoxylon* Schenk, 1882

Palmoxylon mathuri Sahni

Pl. 29, figs 7-10

1964 *Palmoxylon mathuri* Sahni, p. 40, pl. 4, figs 33, 34; pl. 5, fig. 35.

Description (based on Sahni, 1964) — *Fibrous bundles* very slender, averaging about 0.09 mm in thickness, 4-7 (usually 5) per mm², badly preserved, stegmata absent, central bundles small, 0.3-0.4×0.5-0.6 mm in size, irregularly oriented in an extraordinarily spongy ground tissue, showing very little variation in form and size, sparse, 24-25 cm²; fibrovascular ratio about 2/3, sclerenchyma badly preserved, reniform in outline, sinus deep, rounded, xylem bivasal, sometimes accompanied by a group of smaller ones on the inner side, in which case fibrovascular ratio further reduced and may be as low as 1/8, two main vessels may be separate and round or (less frequently) contiguous and flattened on their medial sides, being surrounded by a sheath of thick-walled parenchyma with cells either isodiametric or a few times higher than wide, pitting on the vessel wall fine, multiseriate, scalariform. General *Ground tissue* extremely lacunar, the trabecular cells forming a loose network with very large meshes.

Figured slide — B.S.I.P. no. 8367.

Occurrence — Near Lakhanpur or Lacknipur (23°42′N: 69°E), exact horizon not known, presumed to be Tertiary.

Comparison and discussion — The significant feature of this palm is the reniform outline of the sclerenchyma in the cross section of the fibrovascular bundles. Hence, it was placed in the *Reniformia* type of palms by Prof. Sahni.

Palmoxylon seriatum Sahni

Pl. 30, figs 1-6

1964 *Palmoxylon seriatum* Sahni, p. 45, pl. 15, figs 97-101.

Description (based on Sahni, 1964) — *Stem:* Fibrous bundles and radial plates composed of thick-walled tangentially elongated cells present in the dermal zone; dermal and subdermal bundles arranged in more or less regular radial series; dermal bundles 110-140/cm², almost contiguous, about 0.7×0.5 mm across, fibrovascular ratio 3-6/1, sclerenchyma deeper radially than broad, sinus angular (about 90°), sometimes slightly round at the top, lobes acute-angled but rounded at their ends; xylem generally bivasal, sometimes an additional group of secondary vessels present covered by a feebly developed ventral sclerenchymatous arch, general ground tissue relatively compact with small intercellular spaces, cells generally thin-walled, round at places, thick-walled cells also present, scattered in the ground tissue; tabular parenchyma forming 1-2 layers over sclerenchyma; subdermal bundles larger, further apart and less regularly arranged in radial rows, 52-66/cm, fibrovascular ratio 2-4/1, radial plates absent, sinus wider than in dermal bundles, xylem bivasal; ground tissue devoid of sclerotic cells and fibrous bundles, cells round to oval; bundles of central region not serially arranged, 29-41/cm², sclerenchyma becoming still less deep

in anteroposterior plane, sinus somewhat more open.

Root — About 7 mm thick, with stele averaging 1.5 mm in diameter, cortex 2.3-2.8 mm in width, large radiating air spaces present in the wide middle cortex, outer cortical zone thinner, central zone compact, fairly wide; pith surrounded by a ring of about 15-19 large round vessels, protoxylem vessels not preserved, phloem indistinguishable.

Figured slide — B.S.I.P. no. 8368.

Occurrence — Exact place and horizon of the specimen not known, presumed to be Tertiary.

Comparison and discussion — The general anatomical structure of this fossil indicates its affinity with *Corypha*-like palms.

DISCUSSION

All the hitherto known Tetiary plant megafossils of Kachchh can be divided into two broad groups — Algae and Phanerogams. The algal fossils are representatives of the subfamily Melobesoideae which includes crustose forms of the calcareous red algae belonging to the family Corallinaceae. Except for one gymnosperm (*Podocarpoxylon*) all the higher plants are angiosperms. Considering the collective evidence of these two groups the following conclusions can be drawn about the palaeoecology and palaeophytogeography of Kachchh during the Tertiary period.

Algae — The number of algal taxa is very small, there being only 8 species belonging to 5 genera. Of these, 3 species representing two genera, *Lithothamnium* and *Lithophyllum*, have been reported from the Eocene and 5 species belonging to four genera, *Lithophyllum*, *Mesophyllum*, *Archaeoporolithon* and *Aethesolithon*, from the Miocene deposits. Obviously, the evidence provided by these few taxa is too meagre to draw any detailed conclusions. However, they do indicate definite marine habitat with normal salinity. The fossil localities lie adjacent to the Tropic of Cancer and hence fall in the tropical region. Moreover, the evidence of the fossils of higher plants also indicate tropical conditions. Thus the climate around these Eocene and Miocene algae must also have been tropical. However, *Lithothamnium* and *Mesophyllum* are primarily cold water genera (Wray, 1977, p. 67). Structurally *Lithothamnium* and *Archaeolithothamnium* are indistinguishable except in the character of reproductive structures. Similarly *Mesophyllum*, *Lithophyllum* and *Neogoniolithon* are very much alike except in a few characters, but whereas *Mesophyllum* is a cold water genus, *Lithophyllum* and *Neogoniolithon* are warm water genera. It is thus strongly suggested that the affinities of taxa described as *Lithothamnium* and *Mesophyllum* need a critical investigation based on more and better preserved material, because it is highly improbable that these cold water genera would be flourishing in the tropical seas around Kachchh.

The occurrence of these marine algae in the Eocene and Miocene deposits further indicates that there was transgression of sea in the Kachchh area during these epochs.

Phanerogams — Leaving aside *Palmoxylon mathuri*, *P. seriatum* and *Culmites cutchensis* whose definite provenance is unknown, the Tertiary Phanerogams of Kachchh can be divided into three florules, namely, (i) the Lower Eocene florule of Panandhro, (ii) the Lower Miocene florule of Goyela-Mokra (Khari Nadi Bed) and Naiya Dhun, and (iii) the *Pliocene florule of Baraia, Dhaneti, Kanaiyabe, Mothala, Naliya, Sandhan and Vinjhan. The Eocene florule is represented only by leaf-impressions. Likewise, the Pliocene florule is represented entirely by petrifactions. The Miocene florule, however, consists of both impressions as well as petrifactions.

All the three florules consist of a number of fossil forms comparable to modern plants as listed below:

1. *Lower Eocene florule of Panandhro* — It consists of 9 species, of which 6 have been assigned to modern genera. The remaining three have been placed under

*In Table 1, showing the stratigraphic classification of the Tertiary sediments of Kachchh, Biswas and Raju (1973, p. 39) have given the age of Kankawati Series as Pliocene though on page 45 they have mentioned that " Probable Pliocene age is suggested " for the Sandhan Formation which consists of Kankawati Series. Recently Dr S. K. Biswas has communicated to one of us (J.S.G.) that fossil woods of the Kankawati Series may belong either to the lowermost Pliocene or the uppermost Miocene. However, we are referring them here to Pliocene according to the published records.

the form genus *Dicotylophyllum* Saporta. Its composition is as follows:

FAMILY	FOSSIL TAXA	MODERN COMPARABLE TAXA
Combretaceae	*Terminalia panandhroensis*	*Terminalia crenulata* Heyne ex Roth.
Myrtaceae	*Syzygium kachchhense*	*Syzygium* sp.
Lythraceae	*Lagerstroemia patelii*	*Lagerstroemia speciosa* L. Pers.
Lauraceae	*Cinnamomum eokachchhensis*	*Cinnamomum zeylanicum* Breyn.
Moraceae	*Ficus kachchhensis*	*Ficus tomentosa* Roxb.
Incertae Sedis	*Dicotylophyllum cordatum*	Dicot
	D. panandhroensis	Dicot
	D. quadrinervatum	Dicot
Pandanaceae	*Pandanus eocenicus*	*Pandanus diversus* John
		P. furcatus Roxb.
		P. tectorius Solander

2. *Lower Miocene florule of Goyela-Mokra (Khari Nadi Bed) and Naiya Dhun* — This florule consists of impressions of leaves and a few fruits and seeds and petrified woods belonging to 9 families, 14 genera and 15 species which have been listed below:

FAMILY	FOSSIL TAXA	MODERN COMPARABLE TAXA
Rutaceae	*Murraya khariensis*	*Murraya paniculata* (Linn.) Jack
Leguminosae	*Bauhinia kachchhensis*	{ *Bauhinia phoenicea* Heyne *B. purpurea* Linn.
	Cassia miokachchhensis	*Cassia* sp.
	Leguminocarpon khariensis	Fruit cf. Leguminosae
	Leguminophyllum khariensis	Leaflet cf. Leguminosae
	Leguminosites khariensis	Seed cf. Leguminosae
	Millettia asymmetrica	*Millettia ovalifolia* Kurz
	M. miocenica	*M. auriculata* Baker
Rhizophoraceae	*Ceriops khariensis* kachchhensis	*Ceriops decandra* (Griff.) Ding Hou *C. tagal* (Perr.) C.B. Rob.
Combretaceae	*Terminalia khariensis*	*Terminalia chebula* Retz.
Lythraceae	*Lagerstroemioxylon eoflosreginum*	*Lagerstroemia speciosa* L. Pers.
Sonneratiaceae	*Sonneratioxylon preapetalum*	*Sonneratia apetala* Buck-Ham *S. caseolaris* (Linn.) Engler
Lauraceae	*Cinnamomum miokachchhensis*	*Cinnamomum zeylanicum* Breyn.
Moraceae	*Ficus khariensis*	*Ficus infectoria* Roxb.
Palmae	*Palmacites khariensis*	Palm

3. *Pliocene florule of Baraia, Dhaneti, Kanaiyabe, Kothara, Mothala, Naliya, Sandhan and Vinjhan* — It consists entirely of petrified woods. They belong to 7 families, 14 genera and 18 species as enumerated below:

Family	Fossil Taxa	Modern Comparable Taxa
Podocarpaceae	*Podocarpoxylon kutchensis*	*Podocarpus wallichianus* C. Presl.
Dipterocarpaceae	*Dipterocarpoxylon malavii*	*Dipterocarpus dyeri* Pierre ex De Laness
	D. pondicherriense	*D. indicus* Bedd.
Sterculiaceae	*Pterospermoxylon kutchensis*	*Pterospermum glabrescens* W. & A. *P. reticulatum* W. & A. *P. rubiginosum* Heyne
	Sterculinium kalagarhense	*Sterculia coccinea* Roxb. *S. oblonga* Mast *S. rhinopetala* K. Schum.
Sapindaceae	*Euphorioxylon indicum*	*Euphoria longana* Lamk.
	Schleicheroxylon kachchhensis	*Schleichera oleosa* (Lour.) Oken
Leguminosae	*Millettioxylon indicum*	*Millettia pendula* Benth. *M. prainii* Dunn *Pongamia pinnata* (Linn.) Pierre
	Pahudioxylon sahnii	*Afzelia-Intsia*
	P. assamicum	*Afzelia-Intsia*
	Cynometroxylon holdenii	*Cynometra polyandra* Roxb. *C. ramiflora* Linn.
	Isoberlinioxylon congoense	*Isoberlinia angolensis* (Welw.) Hoyle & Brenan *I. niembaensis* Duvingn
	Dialiumoxylon indicum	*Dialium* sp.
	Albizinium eolebbekianum	*Albizia lebbek* Benth.
	A. pondicherriensis	*Albizia amara* Boivin *A. odoratissima* Benth.
Combretaceae	*Terminalioxylon felixii*	*Terminalia arjuna* Bedd. *T. tomentosa* W. & A.
	T. burmense	*T. tomentosa* W. & A.
Palmae	*Palmoxylon kachchhensis*	Palm

Palaeophytogeography — From a general survey of the above florules it is seen that out of the known modern comparable genera, viz., *Afzelia, Intsia, Albizia, Bauhinia, Cassia, Ceriops, Cinnamomum, Cynometra, Dialium, Dipterocarpus, Euphoria, Ficus, Isoberlinia, Lagerstroemia, Millettia, Pongamia, Murraya, Pandanus, Podocarpus, Pterospermum, Schleichera, Sonneratia, Sterculia, Syzygium* and *Terminalia*, only *Bauhinia, Cassia, Ceriops, Ficus* and *Sterculia* are represented in the present day flora of Kachchh. These five genera are found in protected and limited places in Kachchh. It is obvious from the above data that the other genera were much wider in their distribution and extended up to Kachchh in the western part of the country during the Tertiary period. Amongst these, *Cinnamomum, Dipterocarpus, Euphoria, Murraya, Pterospermum, Schleichera, Isoberlinia* and *Podocarpus* are the important genera from the phytogeographical point of view. Out of them, the first six are primarily Indo-Malayan in distribution, *Isoberlinia* is restricted to tropical Africa and *Podocarpus* is a relict southern hemisphere plant. It shows that the mixing of eastern and western elements had already taken place in India during the Tertiary and Kachchh had been the meeting ground particularly for the African and Arabian elements with the Indian.

On comparing the Kachchh Tertiary flora, specially the Pliocene florule, with the modern plants of the neighbouring

areas it can be observed that almost all the elements of the Pliocene florule are found South of Kachchh along the western coast of India. It seems that with the later deterioration in climatic conditions, this flourishing Pliocene florule died down in Kachchh while its counterparts continued southwards along the western coast.

Palaeoecology — In general the composition of the Lower Eocene, Lower Miocene and Pliocene florules, considered with respect to their modern comparable forms, indicates a tropical climate in which these florules had flourished. Champion and Seth (1968, p. 45) have divided the tropical vegetation of India into the following seven forest types, viz., wet evergreen forests, (ii) semi-evergreen forests, (iii) moist deciduous forests, (iv) littoral and swamp forests, (v) dry deciduous forests, (vi) thorn forests, and (vii) dry evergreen forests, on the basis of moist conditions.

The modern equivalent of the Lower Eocene florule are distributed in the following types of tropical forests:

Taxa	Tropical Forest Types						
	Wet evergreen forests	Semi evergreen forests	Moist deciduous forests	Littoral and swamp forests	Dry deciduous forests	Thorn forest	Dry evergreen forests
Cinnamomum zeylanicum	+	+					
Ficus tomentosa	+	+	+		+		
Lagerstroemia speciosa			+	+			
Pandanus diversus, *P. furcatus*, *P. tectorius*	+	+	+	+			
Syzygium sp.	+	+	+	+	+		+
Terminalia crenulata			+				

The modern comparable forms of the Lower Miocene elements are distributed in the following types of tropical forests:

Taxa	Tropical Forest Types						
	Wet evergreen forests	Semi evergreen forests	Moist deciduous forests	Littoral and swamp forests	Dry deciduous forests	Thorn forests	Dry evergreen forests
Bauhinia phoenicea, *B. purpurea*	+	+	+				
Ceriops decandra, *C. tagal*				+			
Cinnamomum zeylanicum	+	+					
Cassia sp.			+		+	+	
Ficus infectoria			+		+		
Millettia auriculata			+		+		
M. ovalifolia					+		
Murraya paniculata		+	+		+		
Sonneratia apetala, *S. caseolaris*				+			
Terminalia chebula	+		+		+		
Lagerstroemia speciosa			+	+			

The modern corresponding elements of the Pliocene florule are distributed in the following types of tropical forests:

It is important to note that the leaves of both Lower Eocene and Lower Miocene florules are entire margined. The entire-

Taxa	Tropical Forest Types						
	Wet evergreen forests	Semi evergreen forests	Moist deciduous forests	Littoral and swamp forests	Dry deciduous forests	Thorn forests	Dry evergreen forests
Afzelia bijuga				+			
Albizia amara					+	+	+
A. odoratissima			+		+	+	
A. lebbek	+	+	+		+		
Cynometra polyandra	+	+					
C. ramiflora				+			
Dialium sp.	+						
Dipterocarpus dyeri	+						
D. indicus	+						
Millettia pendula			+		+		
M. prainii			+				
Euphoria longana	+						
Podocarpus wallichianus	+						
Pongamia pinnata				+	+		
Pterospermum glabrescens							
P. reticulatum	+	+					
P. rubiginosum							
Schleichera oleosa	+	+	+		+		
Terminalia arjuna			+	+	+		
T. tomentosa		+	+		+		

From the foregoing tables it is clear that the modern equivalents of the fossil genera are not restricted to any particular type of tropical forest in any of the three florules. Broadly speaking, the above noted floristic assemblages are climatically an admixture of evergreen to deciduous elements.

From the components of the Lower Eocene florule it is plausible to conclude that moist evergreen to deciduous vegetation was then prevalent around Panandhro. Further, the littoral and swampy elements indicate the occurrence of marshes around this locality in which the vegetation got buried and in due course resulted in the formation of lignite.

Climatic conditions must have become less moist during the Lower Miocene as is indicated by the majority of elements of the Goyela-Mokra florule, which belong to moist deciduous to dry deciduous forests. This view is further substantiated by the smaller size of leaves and dominance of legumes. The semi-evergreen plants might have been growing in pockets.

margined leaves and leaflets are predominantly found in arctic, alpine, xeric and tropical rainforest environments. The percentage decreases to near equality in the upland tropics and subtropical forests, while the leaves of temperate forests are mainly non-entire as has been pointed out by Sinnott and Bailey (1915), Bailey and Sinnott (1961), Chaney and Sanborn (1933) and Wolfe (1977). Thus on the basis of the morphology of leaves (which provides an additional tool to reconstruct the climatic conditions of the plants growing in a particular region) it can be safely concluded, keeping in view the vegetational assemblages of the Lower Eocene and Lower Miocene florules, that they represent a tropical type of vegetation rather than arctic, alpine or xeric.

During Pliocene, climatic conditions must have again become favourable for the growth of comparatively luxuriant vegetation. The occurrence of evergreen elements like *Dipterocarpus*, *Euphoria*, *Podocarpus* and *Pterospermum*, indicates hot and humid condi-

tions with plenty of rainfall. In addition to these there are also moist deciduous forms like *Albizia*, *Millettia*, *Schleichera* and *Terminalia*. Thus it seems that in general the prevalent vegetation might have been semi-evergreen to moist deciduous. Further, around the streams and ravines some marshy vegetation must also have existed as indicated by the littoral and swampy elements of this florule.

It is important to mention here that the ecological amplitude of *Podocarpus*, the largest genus of all the present day conifer families, is considerable. The podocarps mostly occur in montane tropical forests, but a few also grow in lowland forests and even descend to sea level. Generally they do not form pure forests and are said to be found mixed with angiosperms in rich lowland tropical forests. Hence, the presence of *Podocarpus* in Kachchh in association with other evergreen elements is not at all surprising and is quite in accordance with its modern habitat.

In view of the occurrence of both moist evergreen as well as deciduous taxa, the Kachchh flora can be placed under the category of the 'Moist tropical semi-evergreen to deciduous forests'.

Thus, in contrast to the dominant scrubby vegetation of today, the vegetation of Kachchh during the Lower Eocene, Lower Miocene and Pliocene was much better and luxuriant. All this provides a strong evidence to the view that the present xeric conditions in this part of India is the result of Post-Pliocene changes in the climatic conditions.

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EXPLANATION OF PLATES

PLATE 1

1. *Lithothamnium* sp. cf. *L. bofilli* Lemoine. × 100. Slide no. 5919/1.
2. *Lithophyllum* sp. × 100. Slide no. 5920/1.
3. *Lithothamnium* sp. cf. *L. validum* Foslie. × 100. Slide no. 5918/1.

PLATE 2

1. *Terminalia panandhroensis* leaf. Natural size.
2-4. *Cinnamomum eokachchhensis*, leaves showing variations in shape and size. Natural size.
5. *Syzygium kachchhense*, leaf. Natural size.

PLATE 3

1. *Syzygium kachchhense*, part of fig. 5 of Plate 1 enlarged showing details of venation. × 3.
2. Another specimen of *Syzygium kachchhense*. Natural size.
3. *Ficus kachchhensis*, leaf. Natural size.
4. *Dicotylophyllum quadrinervatum*, leaf. Natural size.

PLATE 4

1. *Lagerstroemia patelii*, leaf. Natural size.
2. *Dicotylophyllum cordatum*, leaf. Natural size.

PLATE 5

1. *Dicotylophyllum panandhroensis*, leaf. Natural size.

PLATE 6

1. *Pandanus eocenicus*, leaf showing venation and spinules. Natural size.
2. Counter part of the specimen. Natural size.

PLATE 7

1, 2. *Lithophyllum* aff. *L. kladosum* Johnson.
1. Showing part of the hypothallus, perithallus and conceptacle. × 150.
2. Perithallial tissue and conceptacle with a single aperture. × 300.
3. *Mesophyllum commune* Lemoine. × 100.
4. *M. commune*, enlarged showing the conceptacle. × 300.

PLATE 8

1. *Mesophyllum commune*, enlarged further. × 300.
2. *Aethesolithon problematicum*. × 70.
3. *A. problematicum*. × 70.
4. *A. cutchensis*. × 50.

PLATE 9

1. *Aethesolithon cutchensis*, enlargement showing the nature of cells. × 150.
2. *Archaeoporolithon miocenicum*, showing hypothallus, perithallus (P) and the megacells in the perithallial tissue. × 70.
3. *A. miocenicum*, showing the arrangement of the megacells. × 150.
4. *A. miocenicum*, showing the arrangement of the megacells. × 100.

PLATE 10

1. *Murraya khariensis*, leaflet. Natural size.
2. Another specimen of *M. khariensis*, leaflet. Natural size.
3. *Cinnamomum miokachchhensis*, leaf. Natural size.
4-6. *Millettia asymmetrica*, leaflets, showing variations in shape and size. Natural size.
7. Another specimen of *Cinnamomum miokachchhensis* leaf. Natural size.
8. A third specimen of *C. miokachchhensis*, leaf. Natural size.
9. *Millettia miocenica*, leaflet. Natural size.

PLATE 11

1. *Bauhinia kachchhensis*, leaf. Natural size.
2. Enlarged photograph of fig. 1, showing details of venation. × 2.
3. *Cassia miokachchhensis*, leaflet. Natural size.
4. Another specimen of *Bauhinia kachchhensis*. Natural size.
5. *Leguminophyllum khariensis*, leaflet. × 2.
6. *Ficus khariensis*, leaf. Natural size.

PLATE 12

1, 3. *Leguminocarpon khariensis*, pods. Natural size.
2, 5. *L. khariensis*, pods showing enclosed seed. Natural size and × 2, respectively.
4, 6. *Leguminosites khariensis*, seeds. × 2.
7. *Leguminophyllum khariensis*, leaflet. Natural size.
8. *Palmacites khariensis*, leaf. Natural size.

PLATE 13

1. *Terminalia kachchhensis* sp. nov., leaf. Natural size.
2. A part of *Terminalia kachchhensis* leaf enlarged to show details of venation. × 2.
3. *Ceriops kachchhensis* sp. nov., leaf. Natural size.
4. *C. kachchhensis* enlarged. × 2.

PLATE 14

Podocarpoxylon kutchensis Lakhanpal, Guleria & Awasthi

1. Cross section showing the nature and distribution of tracheids, xylem rays and growth rings. × 10. B.S.I.P. slide no. 4921-35195/1336.
2. Cross section magnified to show shape, size and distribution of tracheids and growth ring. × 50. B.S.I.P. slide no. 4921-35195/1336.
3. Tangential longitudinal section showing xylem rays. × 85. B.S.I.P. slide no. 4922-35195/1336.
4. Radial longitudinal section showing cross-field pits. × 500. B.S.I.P. slide no. 4923-35195/1336.
5. Radial longitudinal section showing round, circular, uniseriate radial pitting. × 500. B.S.I.P. slide no. 4923-35195/1336.
6. Another radial longitudinal section showing uniseriate to biseriate bordered pits arranged in opposite to sub-opposite fashion. × 500. B.S.I.P. slide no. 4924-35195/1336.

PLATE 15

Dipterocarpoxylon malavii Ghosh & Ghosh

1. Cross section showing the nature and distribution of vessels and gum canals. × 7. B.S.I.P. slide no. 6619.
2. Cross section magnified to show details of vessels, parenchyma and diffuse gum canals. × 50. B.S.I.P. slide no. 6619.
3. Tangential longitudinal section showing xylem rays. × 60. B.S.I.P. slide no. 6620.
4. Radial longitudinal section showing heterocellular rays. × 140. B.S.I.P. slide no. 6621.

Dipterocarpoxylon pondicherriense Awasthi

5. Cross section showing nature and distribution of vessels and gum canals arranged in tangential groups. × 7. B.S.I.P. slide no. 6622.

PLATE 16

Dipterocarpoxylon pondicherriense Awasthi

1. Tangential longitudinal section showing xylem rays. × 60. B.S.I.P. slide no. 6623.

Sterculinium kalagarhense (Trivedi & Ahuja) Guleria

2. Cross section showing the nature and distribution of vessels, parenchyma, rays and tangential row of gum canals. × 10. B.S.I.P. slide no. 6624.
3. Magnified cross section showing details of vessels, parenchyma bands. × 30. B.S.I.P. slide no. 6624.
4. Tangential longitudinal section showing xylem rays. × 50. B.S.I.P. slide no. 6625.
5. Intervascular pitting. × 600. B.S.I.P. slide no. 6625.

PLATE 17

Pterospermoxylon kutchensis Awasthi, Guleria & Lakhanpal

1. Cross section showing nature and distribution of vessels and growth rings. × 7. B.S.I.P. slide no. 5885.
2. Cross section magnified to show the nature and distribution of vessels and parenchyma. × 30. B.S.I.P. slide no. 5885.
3. Cross section further magnified to show details of vessels and apotracheal parenchyma lines. × 90. B.S.I.P. slide no. 5885.

Pterospermum reticulatum W. & A.

4. Cross section showing vessels and apotracheal parenchyma lines similar to those of fossil shown in fig. 3. × 90.

Pterospermoxylon kutchensis Awasthi, Guleria & Lakhanpal

5. Tangential longitudinal section showing tylosed vessel and rays with a tendency towards storied arrangement. × 70. B.S.I.P. slide no. 5886.
6. Radial longitudinal section showing heterocellular rays with tile-cells. × 150. B.S.I.P. slide no. 5887.
7. Intervessel pits. × 500. B.S.I.P. slide no. 5886.

PLATE 18

Pterospermoxylon kutchensis Awasthi, Guleria & Lakhanpal

1. Tangential longitudinal section showing xylem rays with tile-cells. × 140. B.S.I.P. slide no. 5886.

Pterospermum reticulatum

2. Tangential longitudinal section showing similar xylem rays with tile-cells. × 140.

Pterospermoxylon kutchensis Awasthi, Guleria & Lakhanpal

3. Xylem rays magnified to show tile-cells. × 165. B.S.I.P. slide no. 5886.

Euphorioxylon indicum Awasthi, Guleria & Lakhanpal

4. Cross section showing gross features. × 35. B.S.I.P. slide no. 6101.
5. Cross section magnified showing type and distribution of vessels and scanty paratracheal parenchyma. × 90. B.S.I.P. slide no. 6101.

PLATE 19

Euphorioxylon indicum Awasthi, Guleria & Lakhanpal

1. Tangential longitudinal section showing xylem rays. × 120. B.S.I.P. slide no. 6102.
2. Radial longitudinal section showing homocellular rays. × 120. B.S.I.P. slide no. 6103.

Schleicheroxylon kachchhensis Awasthi, Guleria & Lakhanpal

3. Cross section showing vessels and scanty paratracheal parenchyma. × 80. B.S.I.P. slide no. 6104.
4. Cross section under low magnification showing gross features such as nature and distribution of vessels and growth rings. × 30. B.S.I.P. slide no. 6104.

Schleichera oleosa

5. Cross section showing similar gross features as shown in fig. 4. × 30.

Schleicheroxylon kachchhensis Awasthi, Guleria & Lakhanpal

6. Radial longitudinal section showing homocellular rays. × 120. B.S.I.P. slide no. 6106.

Schleichera oleosa

7. Radial longitudinal section showing homocellular rays as in fossil shown in fig. 6. × 120.

PLATE 20

Schleicheroxylon kachchhensis Awasthi, Guleria & Lakhanpal

1. Tangential longitudinal rays showing xylem rays. × 120. B.S.I.P. slide no. 6105.

Schleichera oleosa

2. Tangential longitudinal section showing xylem rays similar to those of fossil shown in fig. 1.

Schleicheroxylon kachchhensis Awasthi, Guleria & Lakhanpal

3. Intervessel pits. × 550. B.S.I.P. slide no. 6105.

Millettioxylon indicum Awasthi

4. Cross section showing vessels and parenchyma bands. × 38. B.S.I.P. slide no. 6677.
5. Tangential longitudinal section showing storied xylem rays. × 120. B.S.I.P. slide no. 6678.

PLATE 21

Pahudioxylon sahnii Ghosh & Kazmi

1. Cross section showing nature and distribution of vessels and parenchyma. × 35. B.S.I.P. slide no. 6665.
3. Tangential longitudinal section showing xylem rays. × 140. B.S.I.P. slide no. 6666.

Pahudioxylon assamicum Prakash & Tripathi

2. Cross section showing nature and distribution of vessels, paratracheal and apotracheal parenchyma. × 32. B.S.I.P. slide no. 6667.
4. Tangential longitudinal section showing xylem rays. × 120. B.S.I.P. slide no. 6668.

PLATE 22

Cynometroxylon holdenii (Gupta) Prakash & Bande

1. Cross section showing the nature and distribution of vessels, parenchyma and rays. × 32. B.S.I.P. slide no. 6669.
2. Tangential longitudinal section showing rays. × 120. B.S.I.P. slide no. 6670.

Isoberlinioxylon congoense Lakhanpal & Prakash

3. Tangential longitudinal section showing rays. × 140. B.S.I.P. slide no. 6672.
4. Cross section showing nature and distribution of vessels and parenchyma. × 10. B.S.I.P. slide no. 6671.
5. Cross section magnified to show vessels, aliform-confluent and narrow line of parenchyma, delimiting the growth ring. × 30. B.S.I.P. slide no. 6671.
6. Radial longitudinal section showing homocellular rays. × 120. B.S.I.P. slide no. 6673.

PLATE 23

Dialiumoxylon indicum Guleria

1. Cross section showing vessels, parenchyma bands and rays. × 50. B.S.I.P. slide no. 6674.
2. Tangential longitudinal section showing storied rays. × 100. B.S.I.P. slide no. 6675.

Albizinium eolebbekianum Prakash

3. Cross section showing vessels and aliform confluent parenchyma. × 40. B.S.I.P. slide no. 6661.
4. Tangential section showing rays. × 120. B.S.I.P. slide no. 6662.

Albizinium pondicherriensis Awasthi

5. Tangential longitudinal section showing rays. × 120. B.S.I.P. slide no. 6663.

PLATE 24

Albizinium pondicherriensis Awasthi

1. Cross section showing vessels, and parenchyma. × 30. B.S.I.P. slide no. 6664.

Terminalioxylon felixii Ramanujam

2. Cross section showing vessels, paratracheal and narrow lines of apotracheal parenchyma. × 15. B.S.I.P. slide no. 6626.
3. Tangential longitudinal section showing uniseriate to occasionally biseriate rays due to pairing of procumbent cells. × 120. B.S.I.P. slide no. 6627.

Terminalioxylon burmense Mädel-Angeliewa & Müller-Stoll

4. Tangential longitudinal section showing uniseriate rays. × 120. B.S.I.P. slide no. 6629.
5. Cross section showing vessels and parenchyma. × 15. B.S.I.P. slide no. 6628.

PLATE 25

Lagerstroemioxylon eoflosreginum Prakash & Tripathi

1. Cross section showing nature and distribution of vessels. × 45. B.S.I.P. slide no. 35763-1.
2. Another cross section showing semi-ring porous nature of wood. × 60. B.S.I.P. slide no. 35763-2.
3. Cross section magnified to show vessels and confluent parenchyma bands. × 60. B.S.I.P. slide no. 35763-3.

Lagerstroemia speciosa

4. Cross section to show resemblance with the fossil in the nature and distribution of vessels and parenchyma. × 50.

PLATE 26

Lagerstroemioxylon eoflosreginum Prakash & Tripathi

1. Tangential longitudinal section showing rays. × 120. B.S.I.P. slide no. 35763-4.
2. Another tangential longitudinal section showing rays mostly uniseriate to occasionally biseriate due to pairing of procumbent cells. × 120. B.S.I.P. slide no. 35763-5.

Lagerstroemia speciosa

3. Tangential longitudinal section to show similarity with the fossil in the nature and distribution of rays. × 120.

Lagerstroemioxylon eoflosreginum Prakash & Tripathi

4. Radial longitudinal section showing homocellular rays. × 170. B.S.I.P. slide no. 35763-6.
5. A portion of tangential longitudinal section showing crystalliferous fibre. × 300. B.S.I.P. slide no. 35763-4.

Sonneratioxylon preapetalum Awasthi

6. Cross section showing nature and distribution of vessels. × 40. B.S.I.P. slide no. 35765-1.

PLATE 27

Sonneratioxylon preapetalum Awasthi

1. Cross section magnified to show vessels and absence of parenchyma. × 120. B.S.I.P. slide no. 35765-1.
2. Tangential longitudinal section showing rays. × 100. B.S.I.P. slide no. 35765-2.
3. Radial longitudinal section showing heterocellular nature of rays. × 120. B.S.I.P. slide no. 35765-3.
4. Tangential longitudinal section showing tylosed vessel. × 120. B.S.I.P. slide no. 35765-4.
5. A portion of tangential longitudinal section magnified to show septate fibres. × 340. B.S.I.P. slide no. 35765-5.

PLATE 28

Palmoxylon kachchhensis Guleria

1. Cross section of the specimen slightly enlarged than natural size.
2. Cross section of the outer zone showing orientation and general distribution of fibrovascular bundles. × 8. B.S.I.P. slide no. 6630.
3. Cross section of inner zone showing orientation and general distribution of fibrovascular bundles. × 8. B.S.I.P. slide no. 6630.
4. Magnified cross section of the inner zone showing the type and orientation of fibrovascular bundles and ground tissue. × 20. B.S.I.P. slide no. 6630.
5. A portion of cross section showing the nature of ground tissue. × 35. B.S.I.P. slide no. 6630.
6. Another portion of cross section magnified to show relatively thick-walled radial plate-like structure. × 30. B.S.I.P. slide no. 6630.

PLATE 29

Culmites cutchensis Sahni

1. Specimen showing glazed surface with well developed longitudinal grove. Natural size G.S.I. C 176 f (reproduced from Sahni, 1964, pl. 1, fig. 9).
2. Another photograph of another piece probably belonging to the same specimen. Natural size.
3. Node of the same. Natural size.

4. Another fragment showing node with dormant bud and leaf sheath. Natural size.
5. Same magnified. × 2.
6. Plasticine cast taken out from the Concave mould of a dormant bud just above the node. (Reproduced from Sahni, 1964, pl. 1, fig. 11).

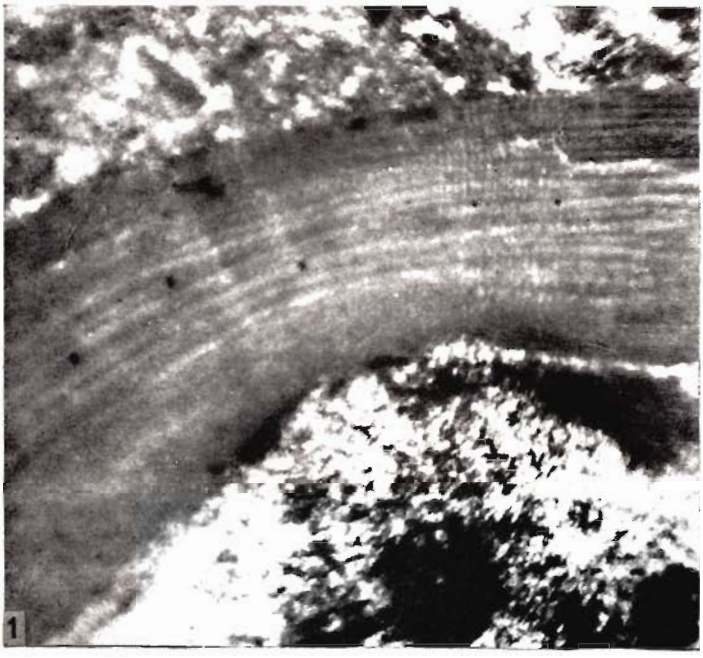
Palmoxylon mathuri Sahni

7. Cross section showing the distribution of fibrovascular bundles. × 12 (Reproduced from Sahni, 1964, pl. 2, fig. 34). B.S.I.P. slide no. 8367.
8. Cross sections showing orientation of fibrovascular bundles and highly lacunar ground tissue. × 28.
9. Same magnified to show details of fibrovascular bundles and ground tissue. × 35.
10. Fibrovascular bundle magnified. × 85.

PLATE 30

Palmoxylon seriatum Sahni

1. Photograph of a transversely cut slab from near the base of the stem with a portion of the attached root. Natural size (Reproduced from Sahni, 1964, pl. 15, fig. 98). B.S.I.P. slide no. 8368.
2. Cross section showing type, distribution and orientation of fibrovascular bundles of the dermal and subdermal region. × 4.
3. A portion of the same section magnified. × 28.
4. Cross section through central region showing orientation of fibrovascular bundles and ground tissue. × 28.
5. A fibrovascular bundle and thick-walled radial plates. (Reproduced from Sahni, 1964, pl. 15, fig. 100).
6. Fibrovascular bundle magnified. × 85.



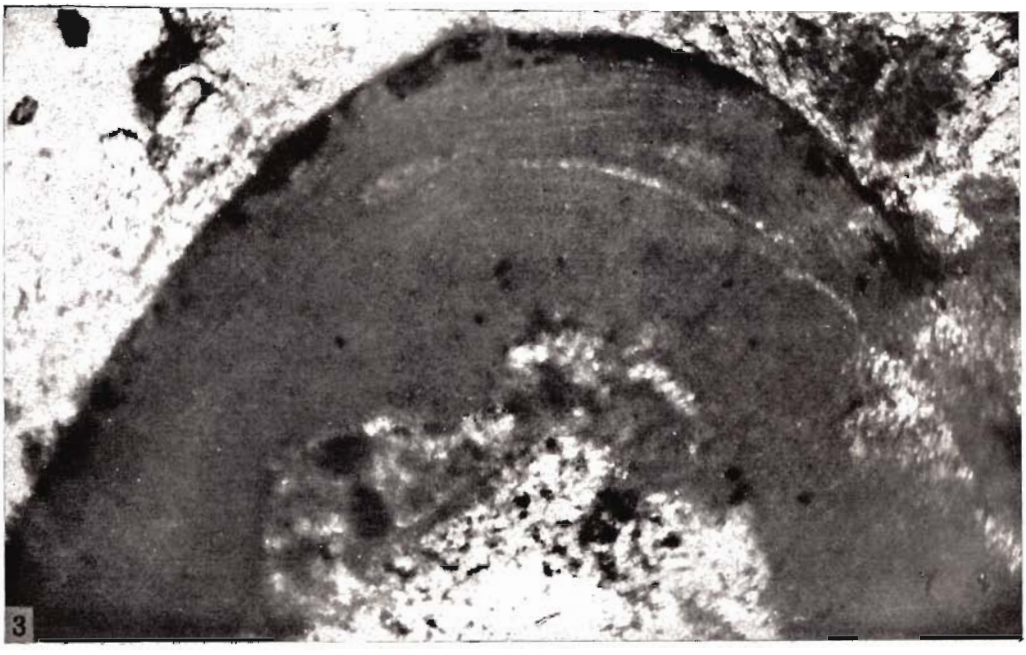
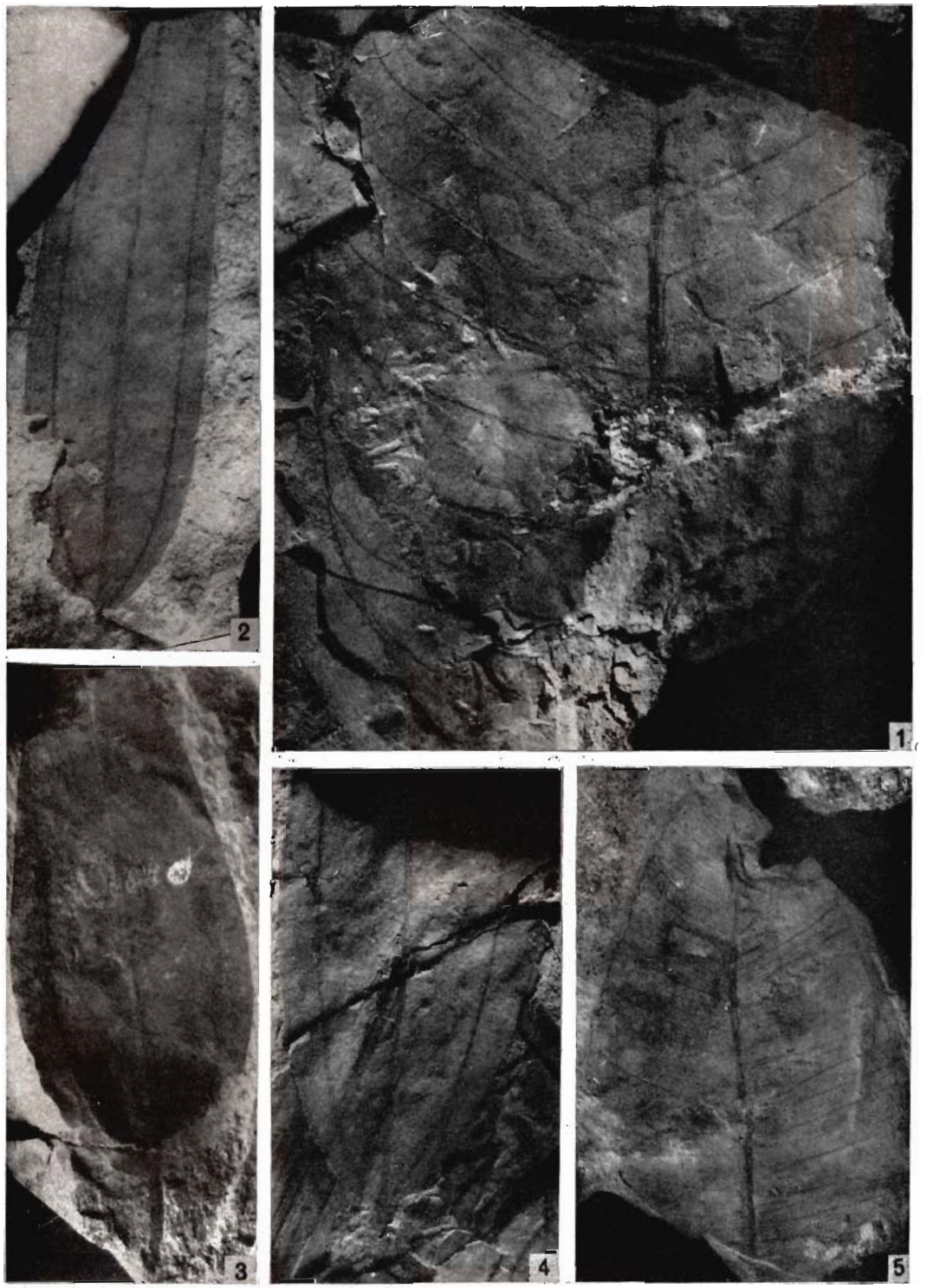


PLATE 1



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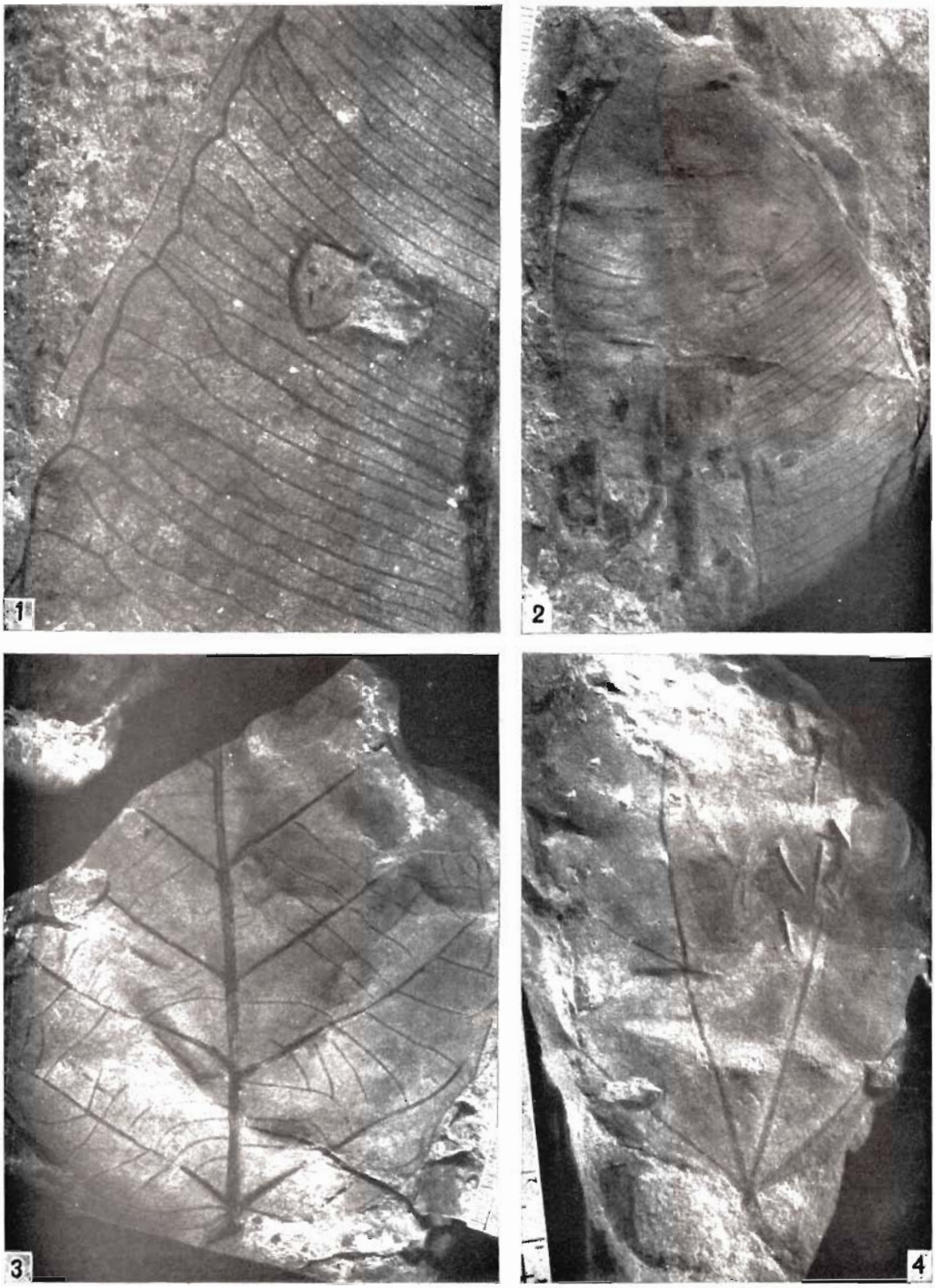

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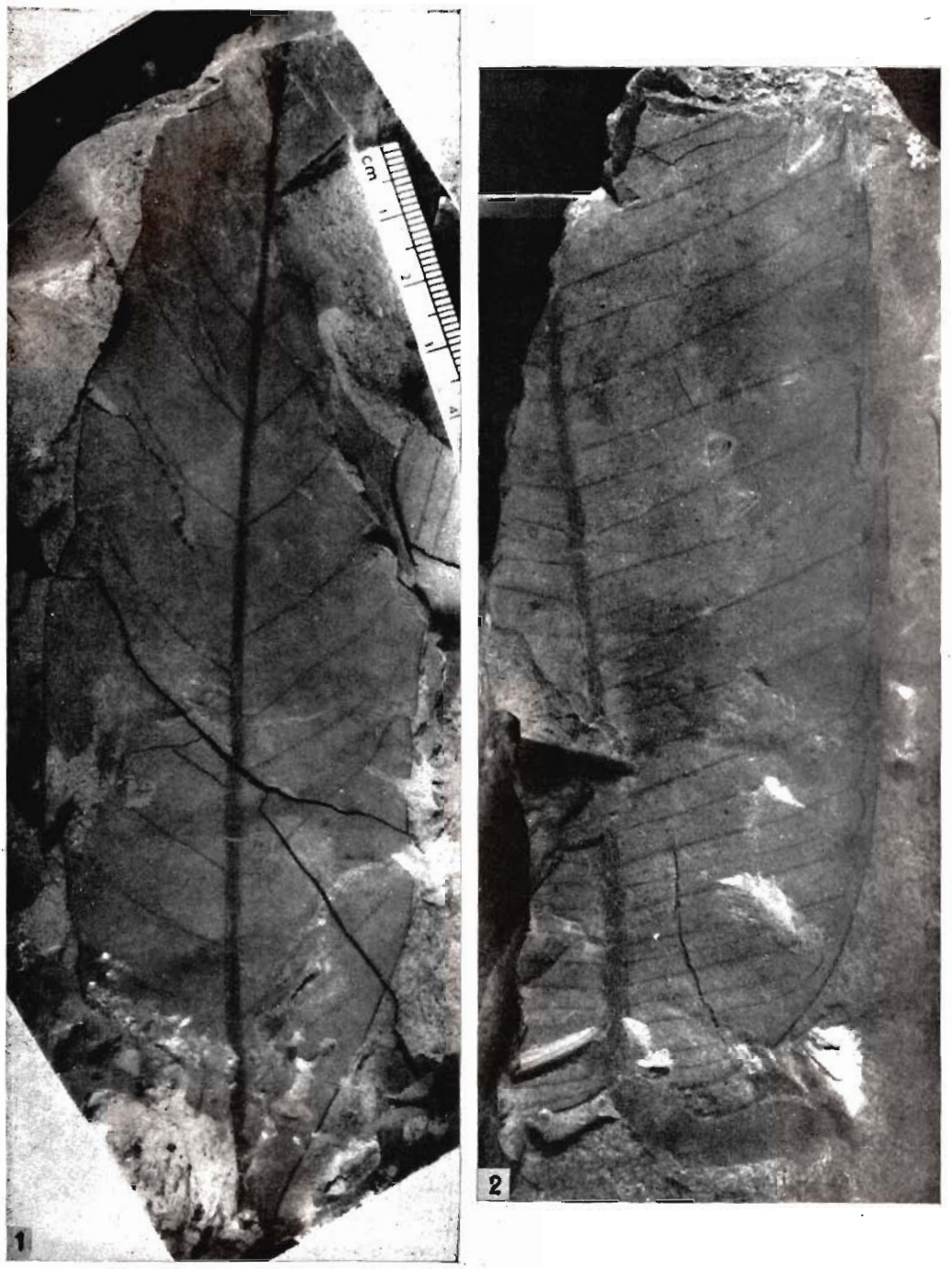

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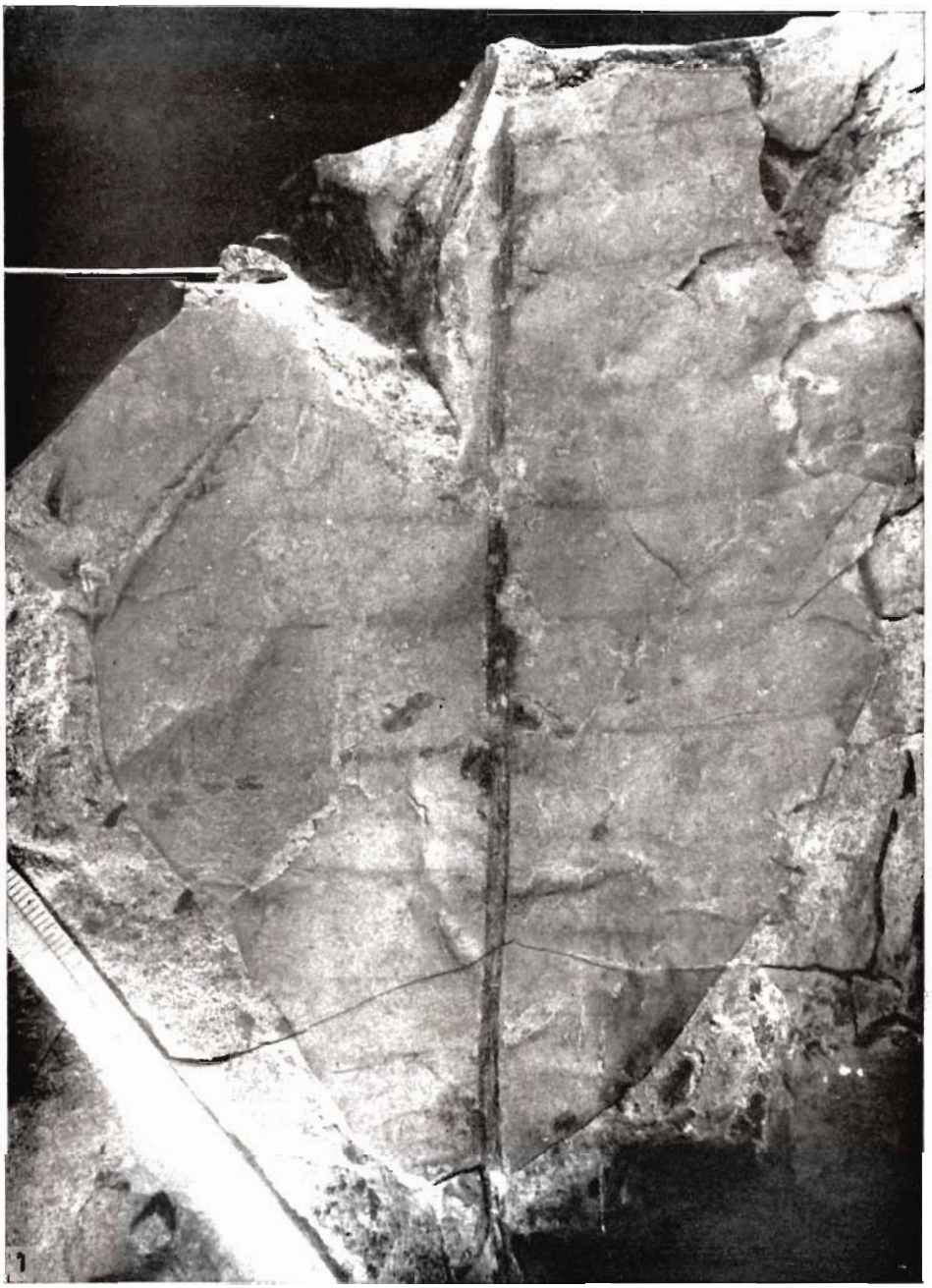

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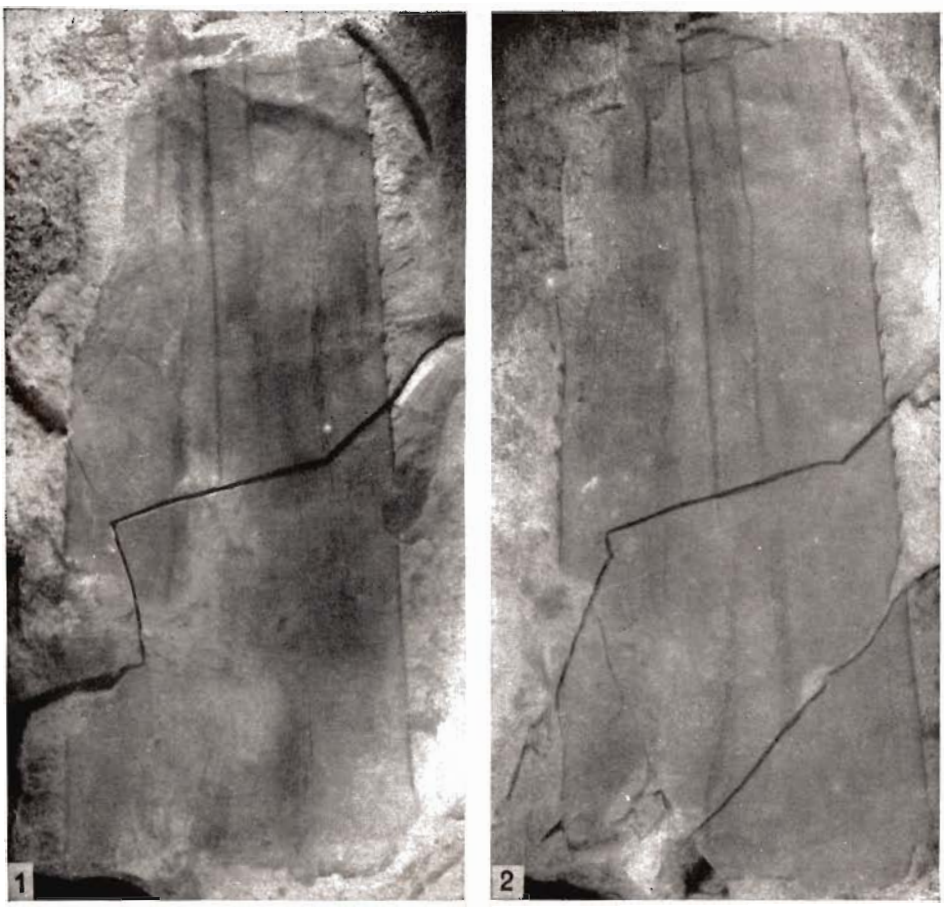

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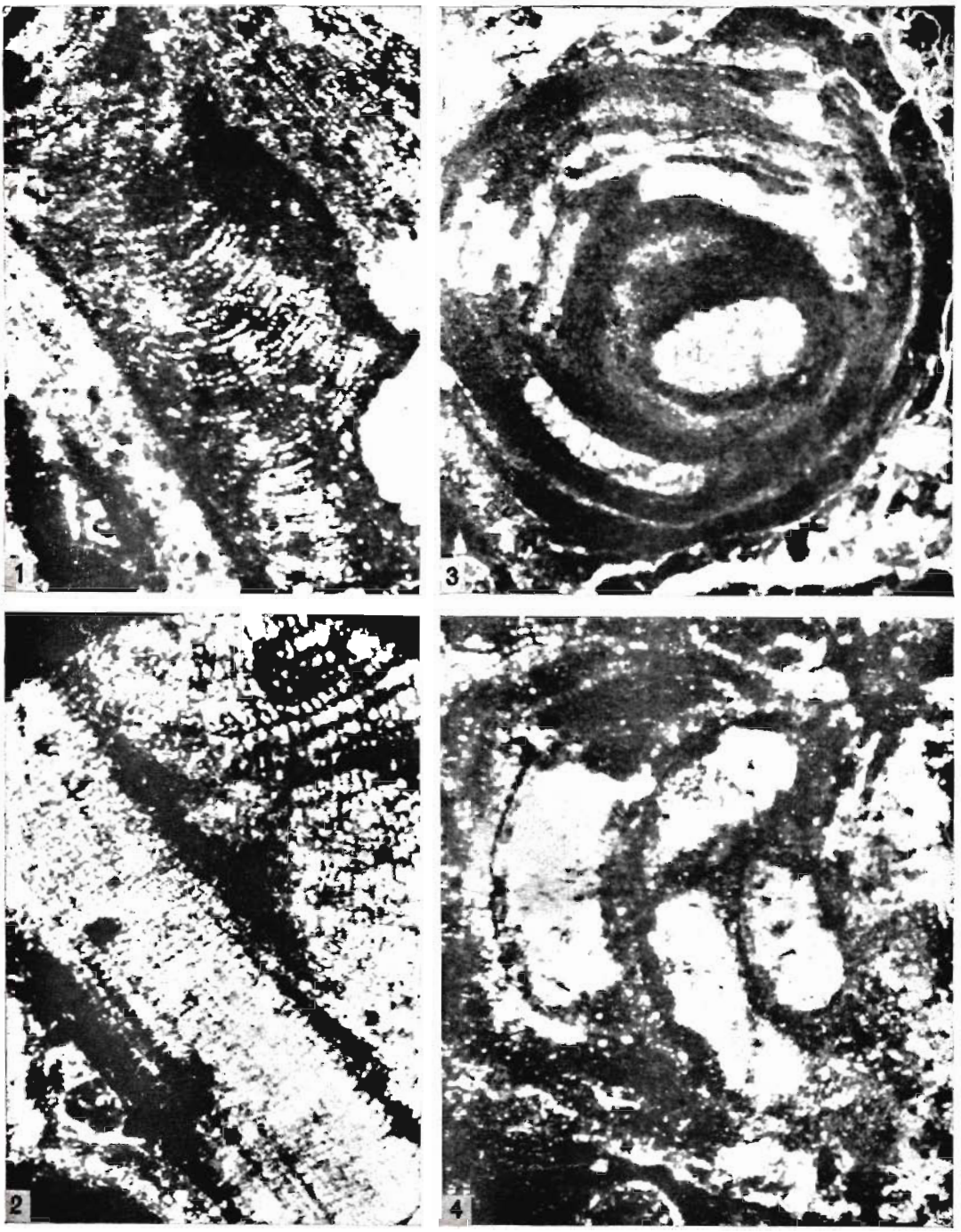

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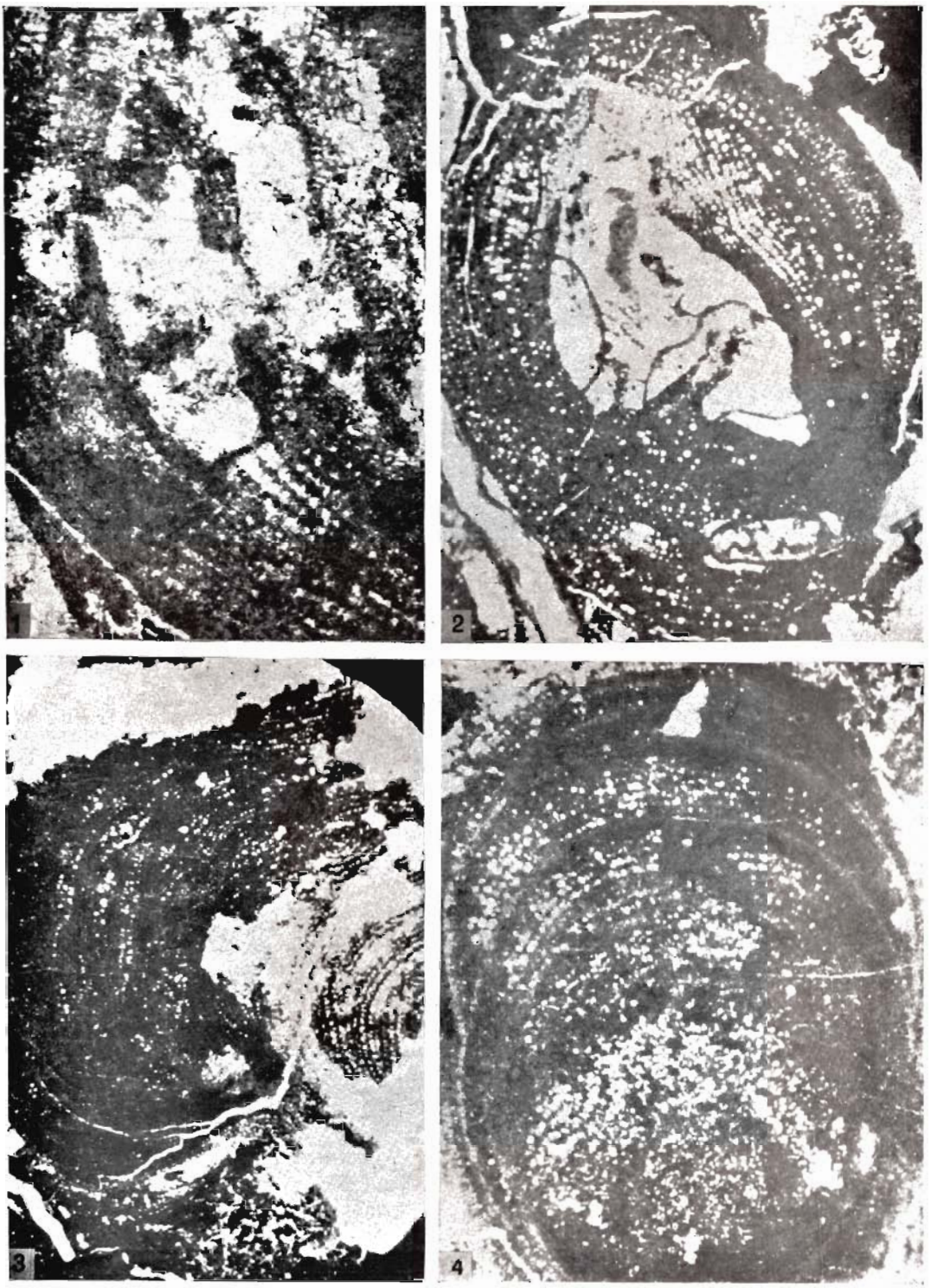

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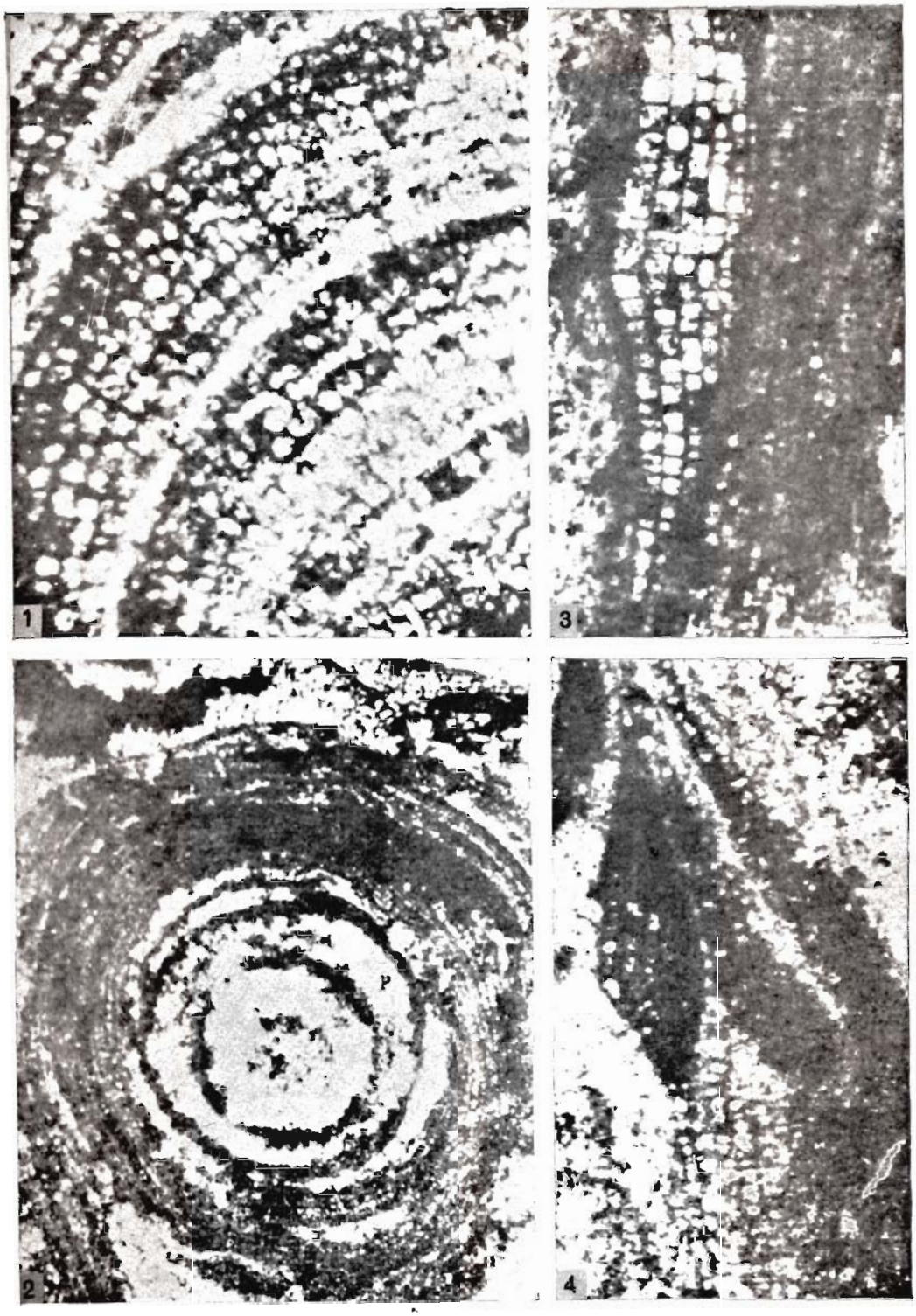

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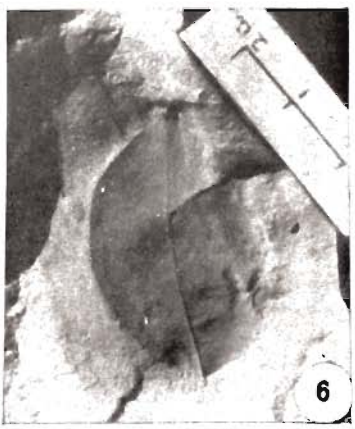

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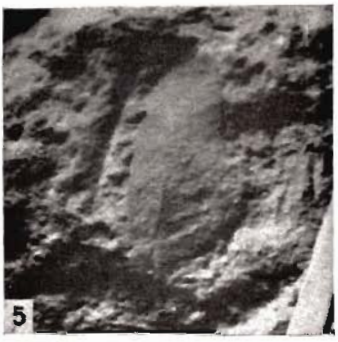

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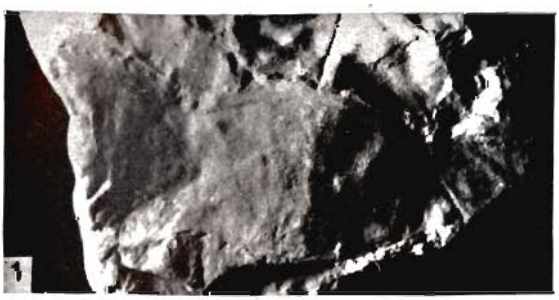

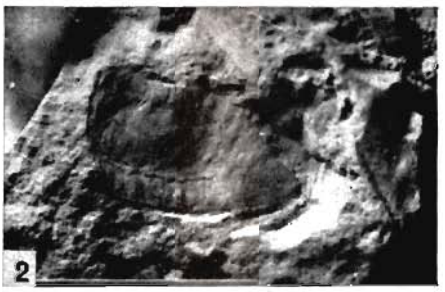

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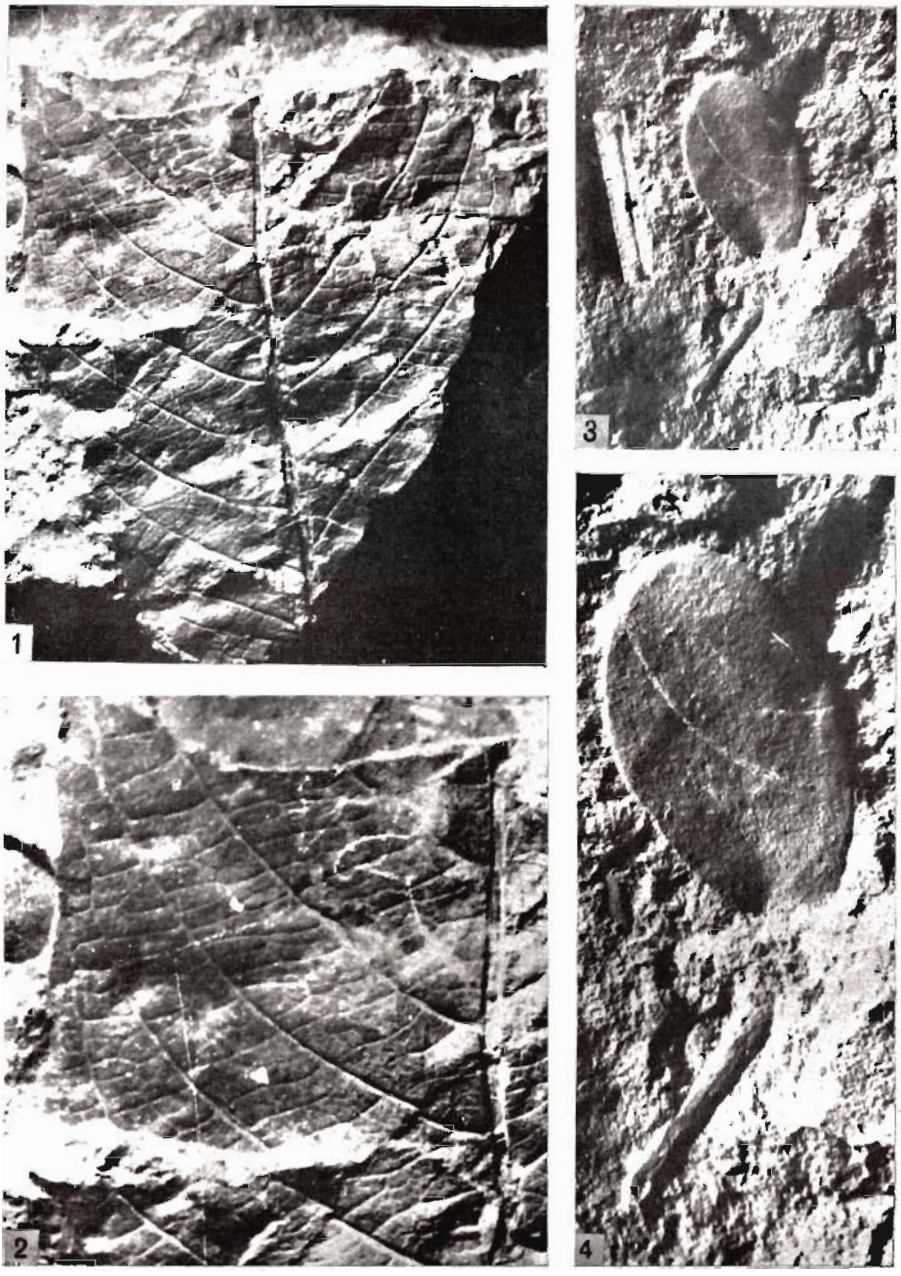

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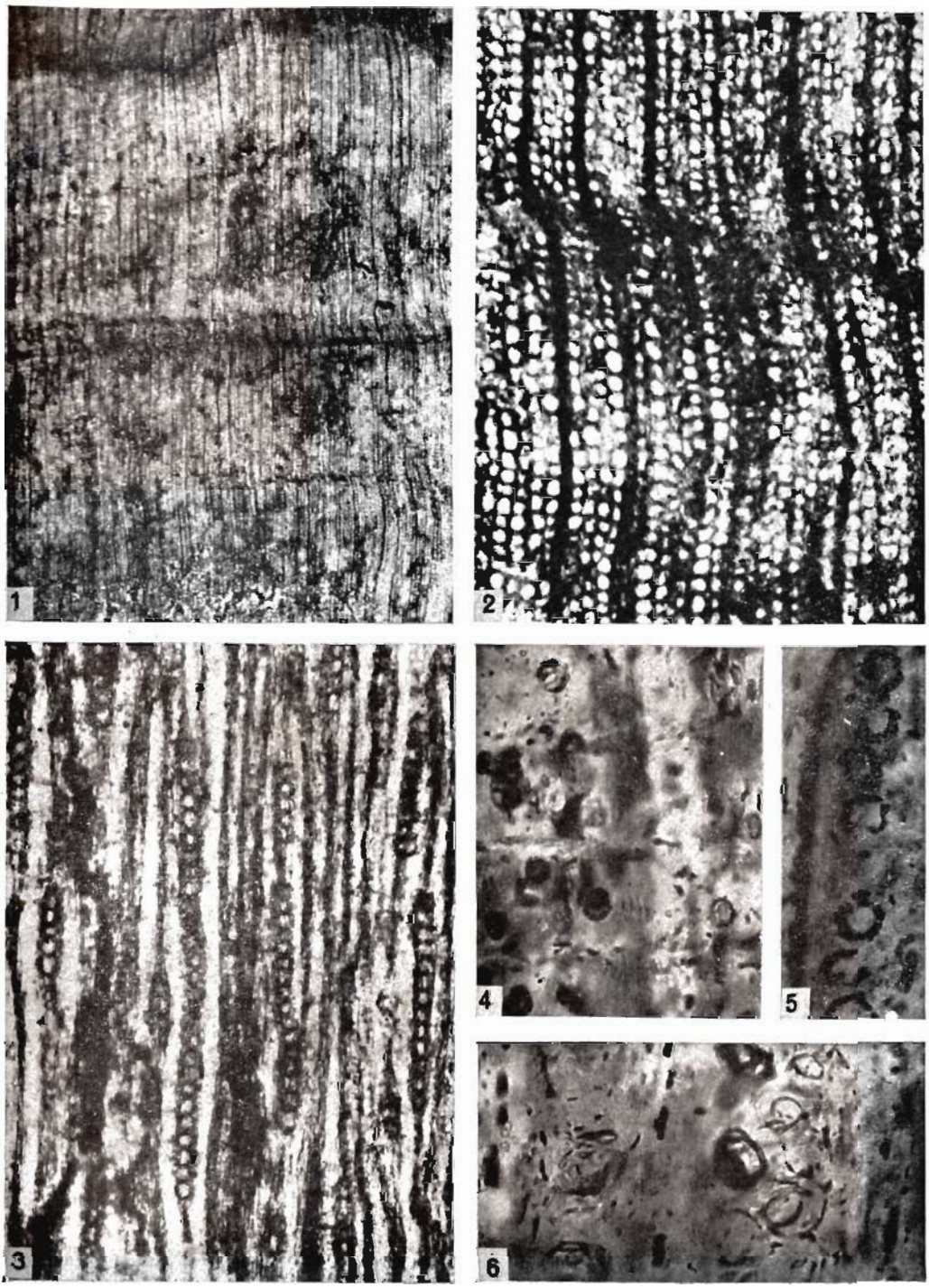

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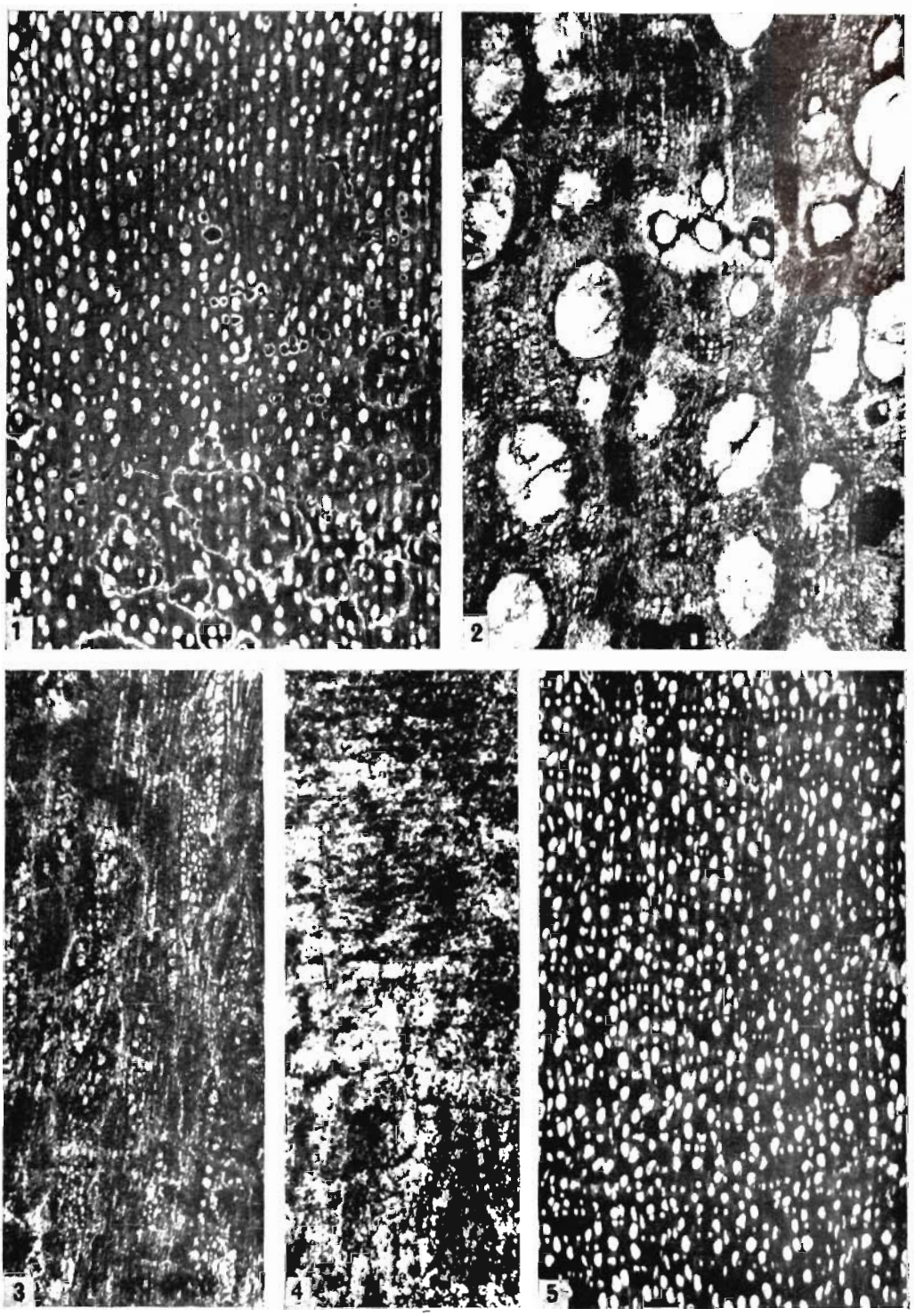

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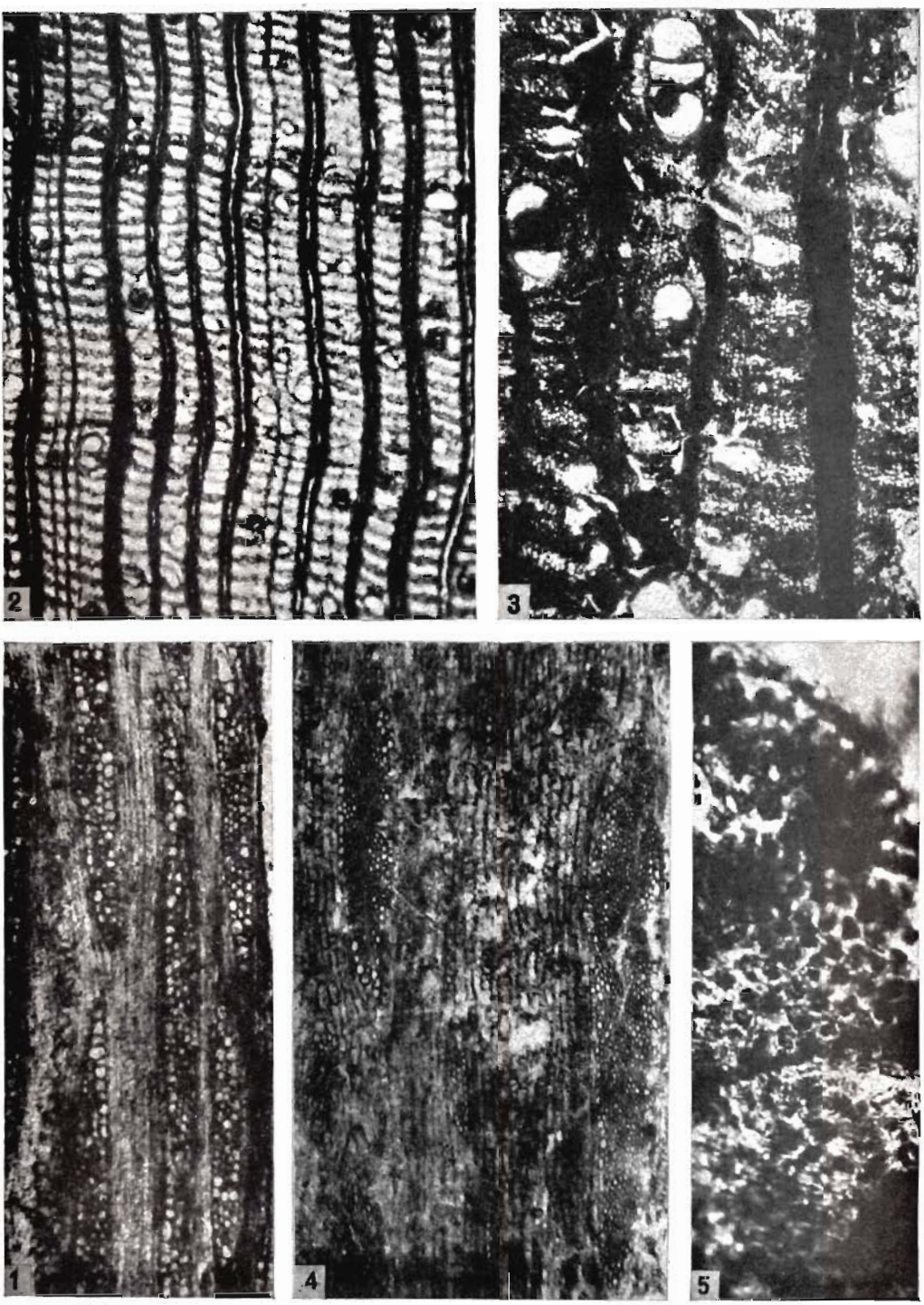

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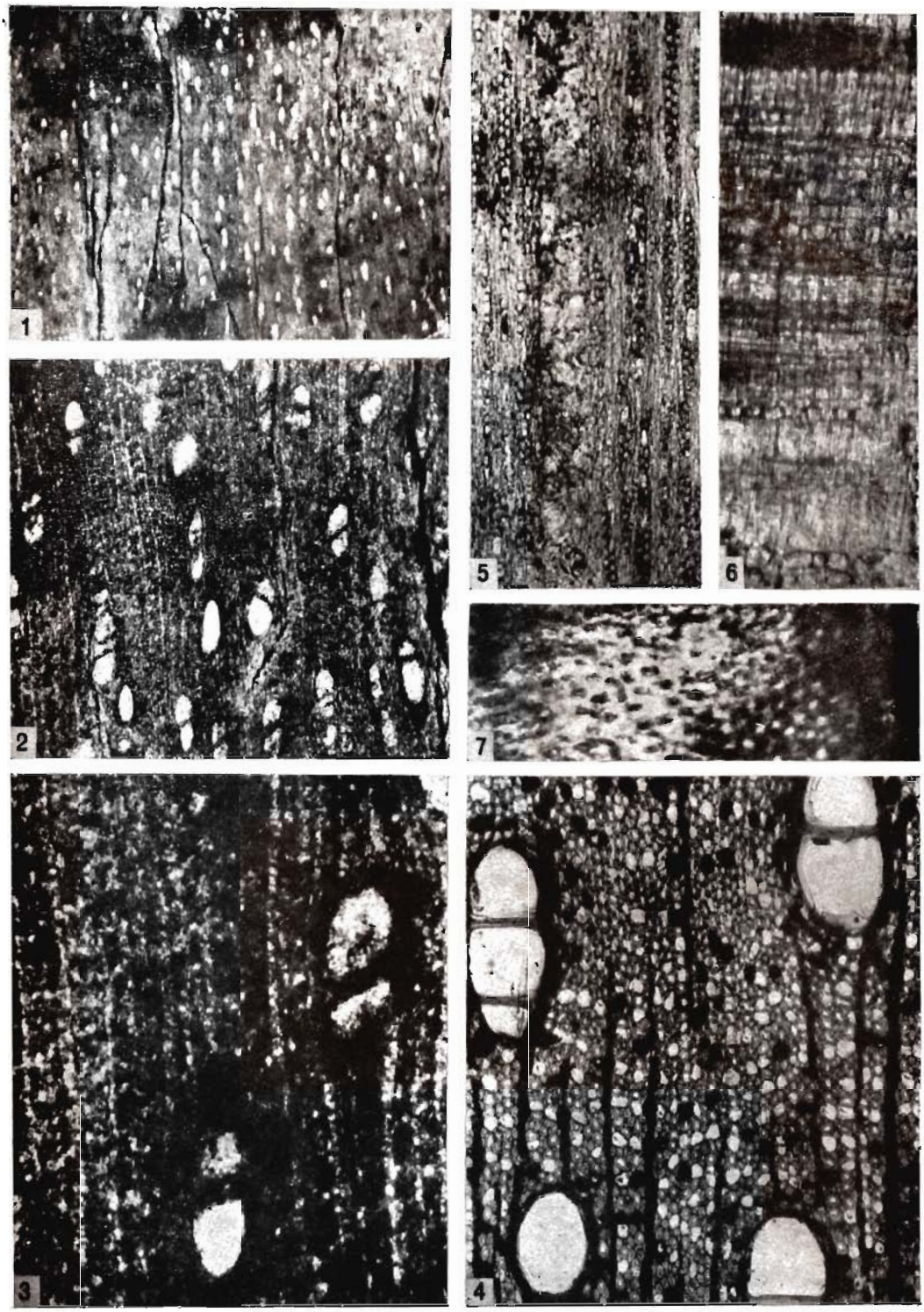

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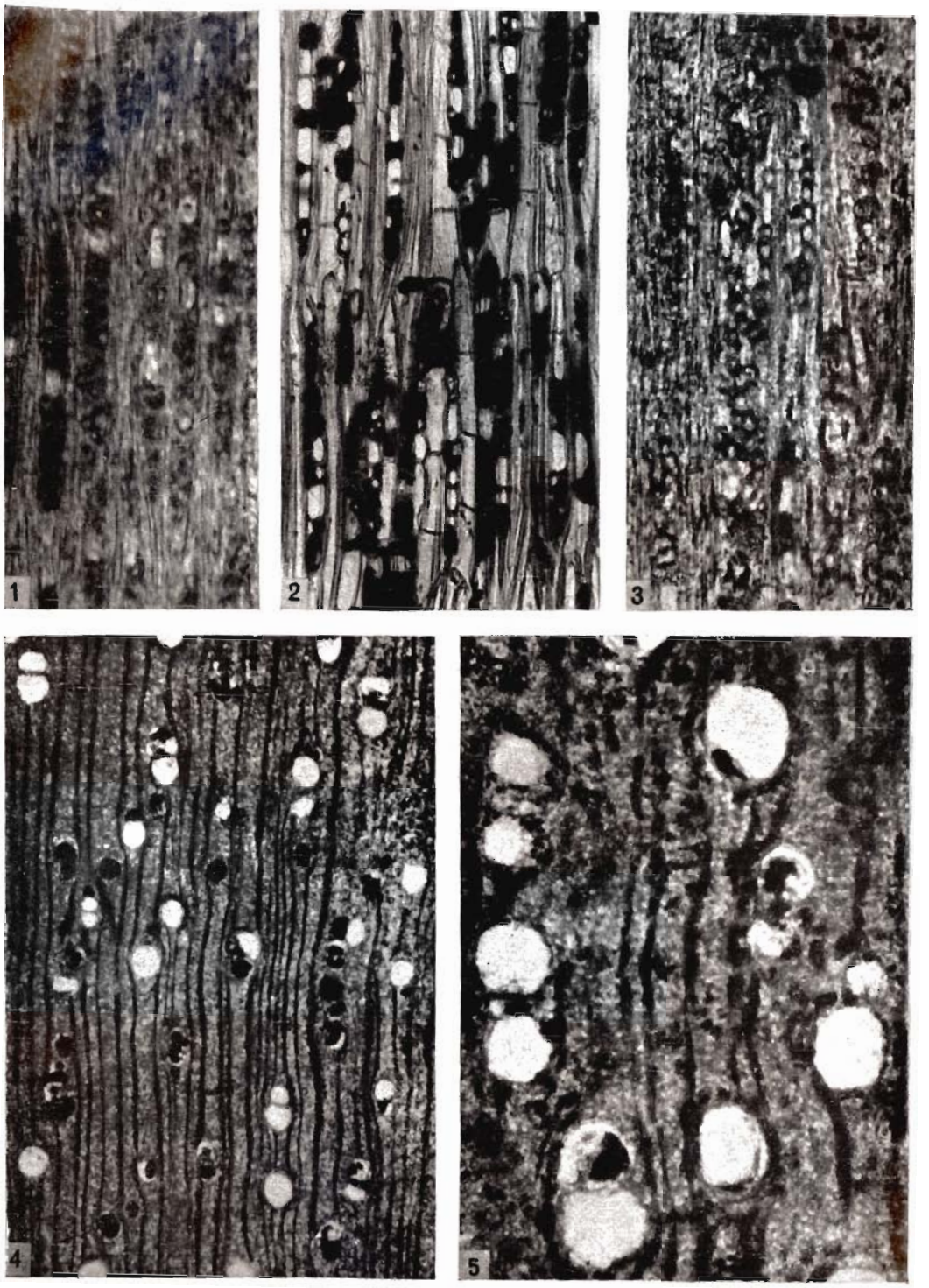


PLATE 18

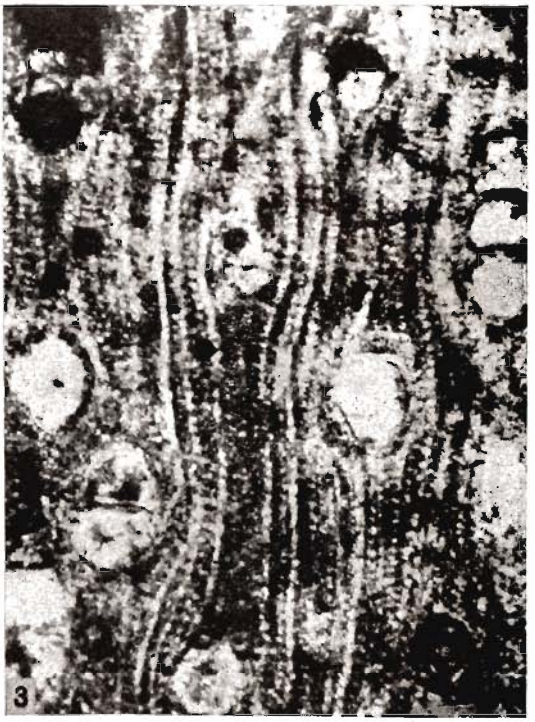
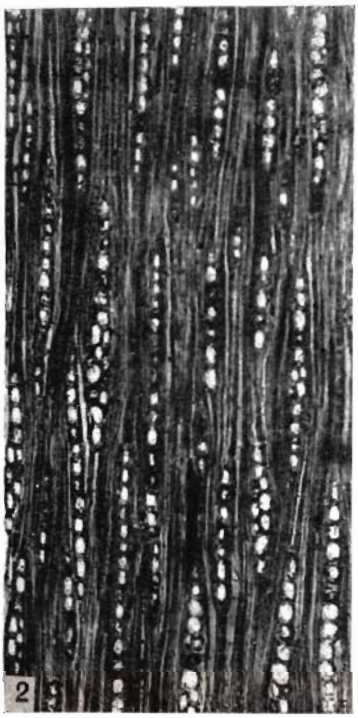
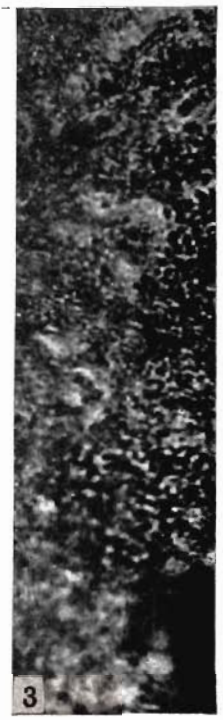


PLATE 19





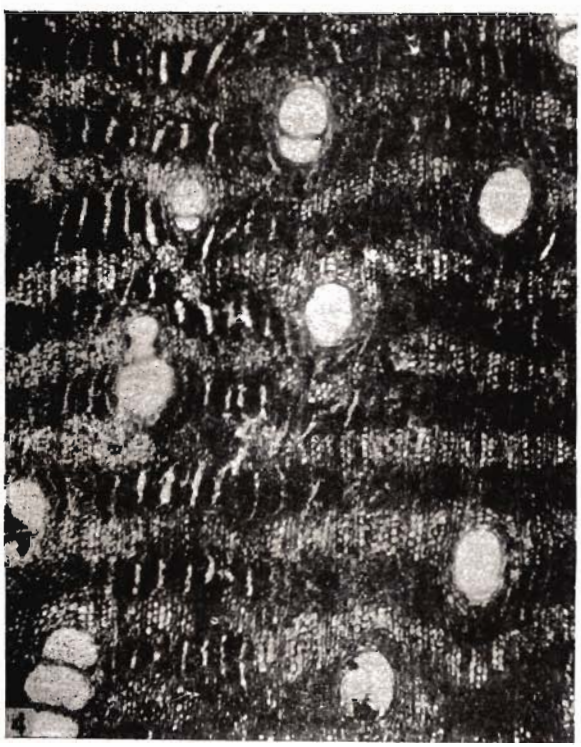


PLATE 20

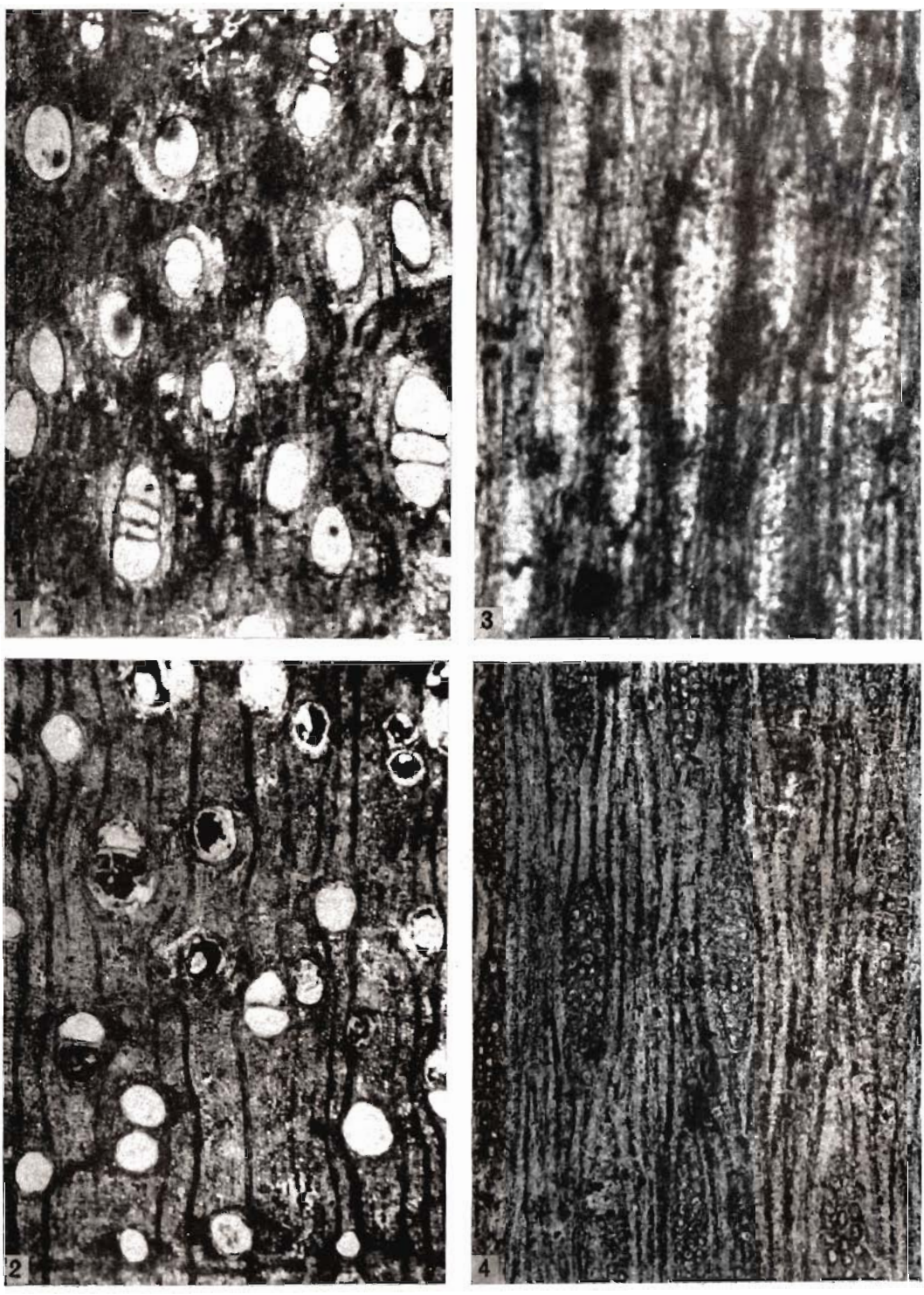


PLATE 21

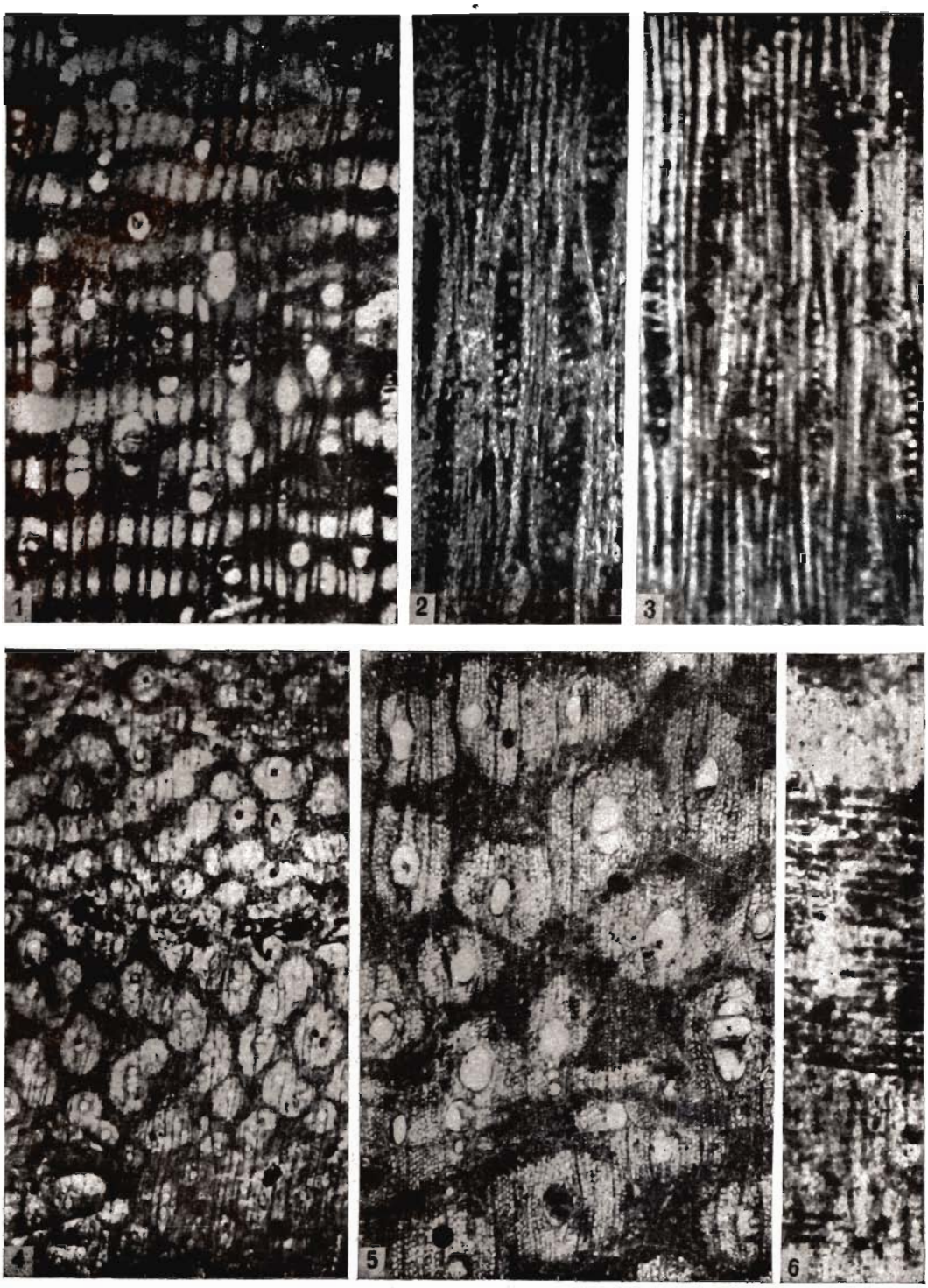


PLATE 22

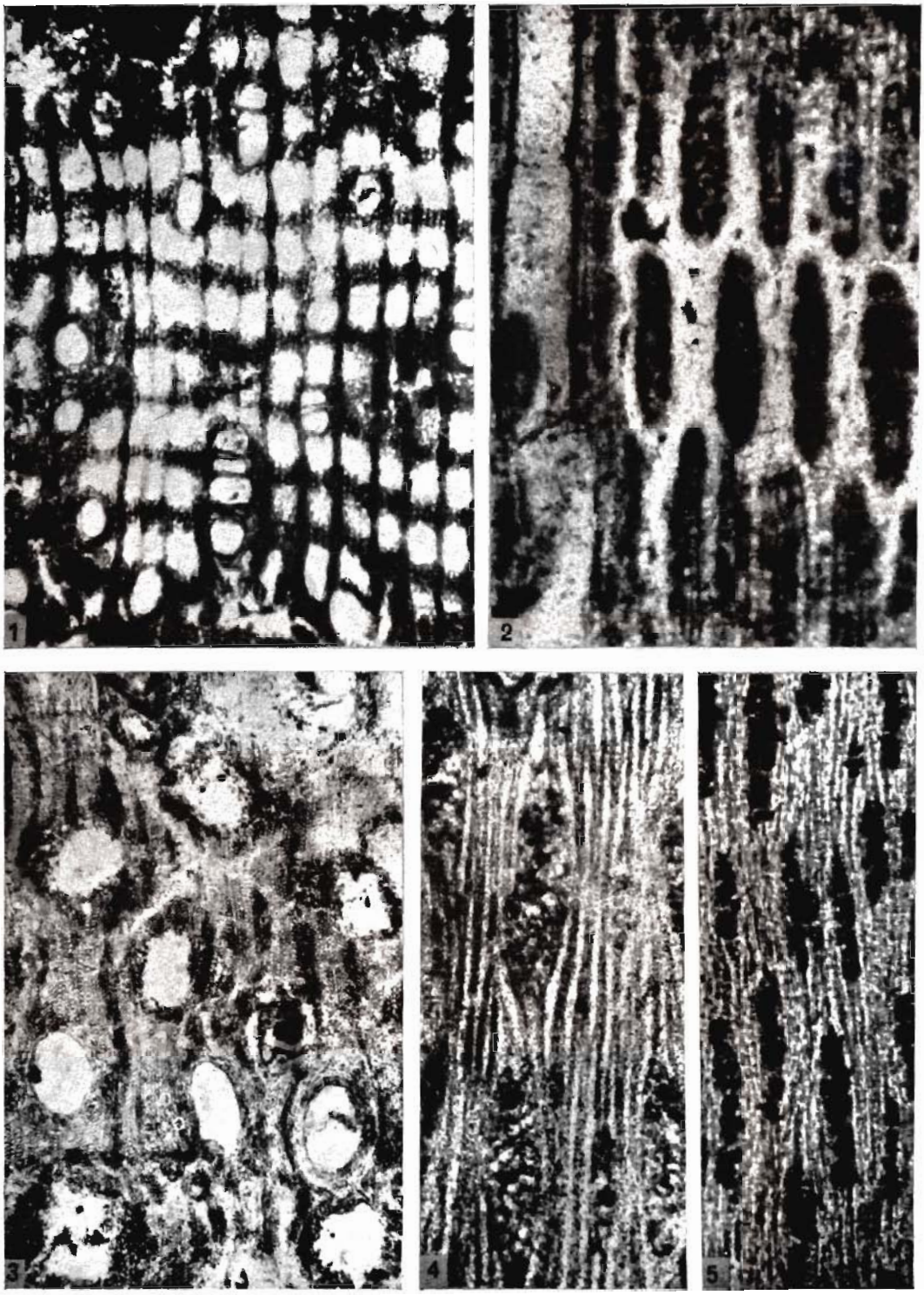


PLATE 23

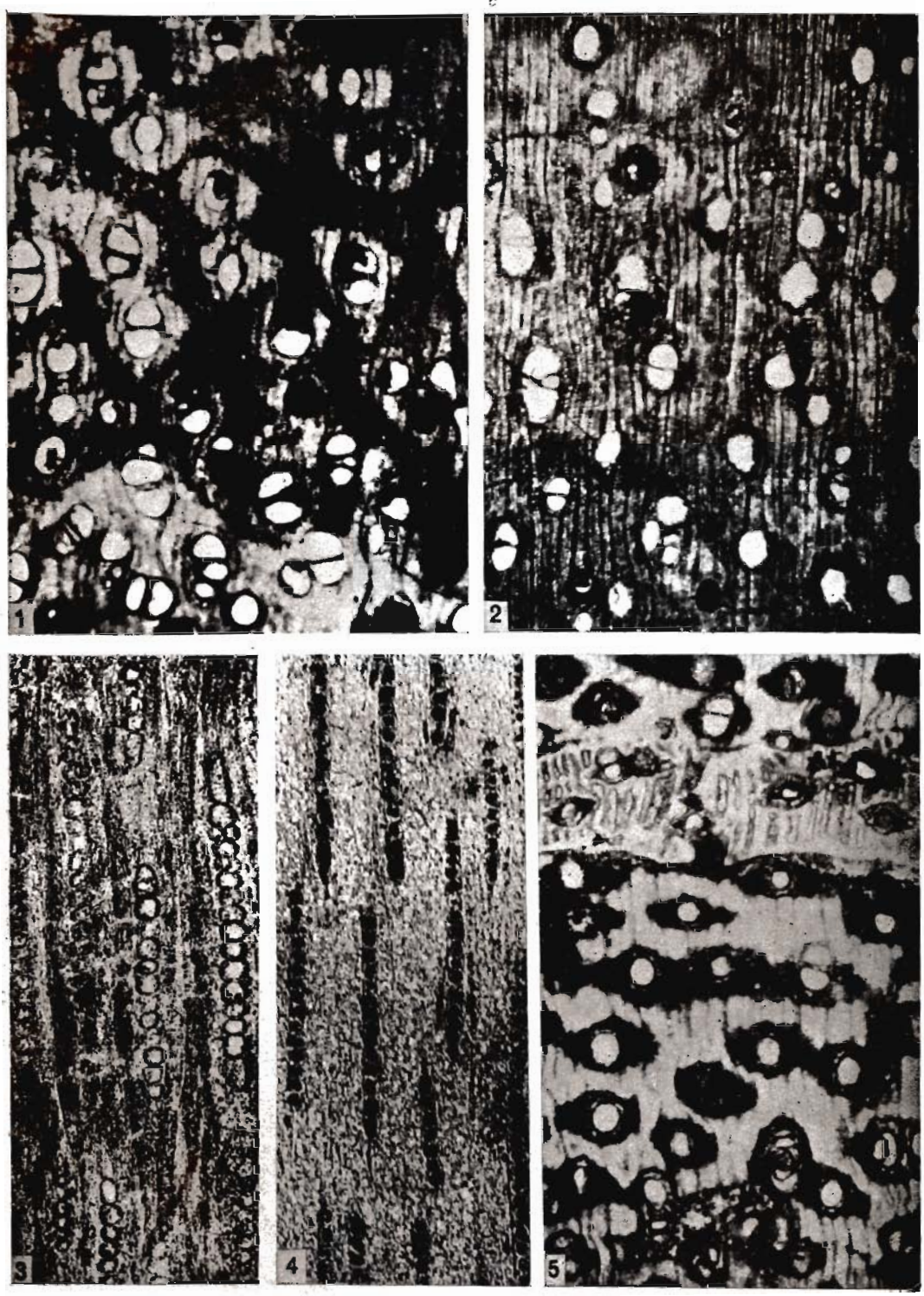


PLATE 24

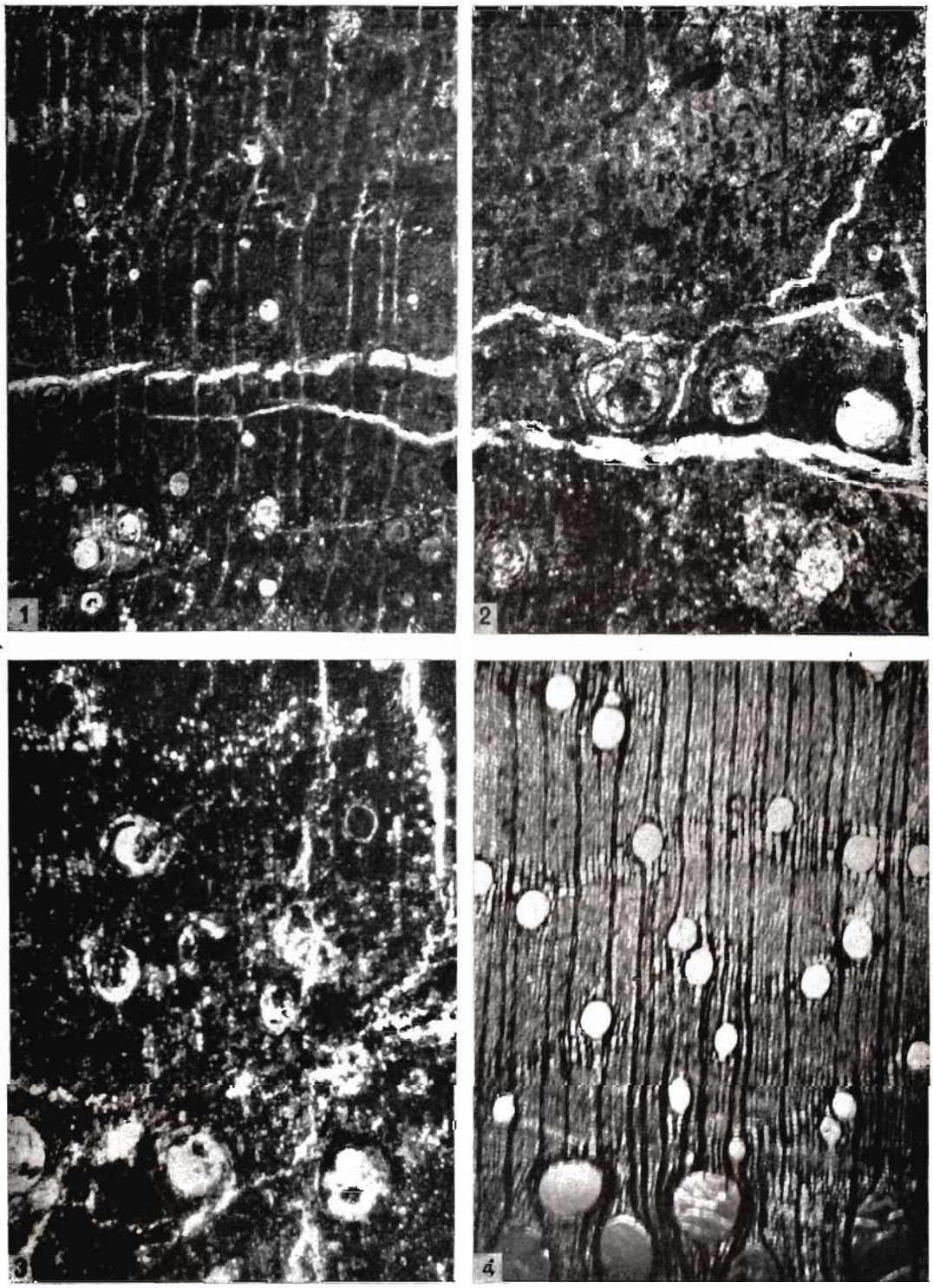


PLATE 25

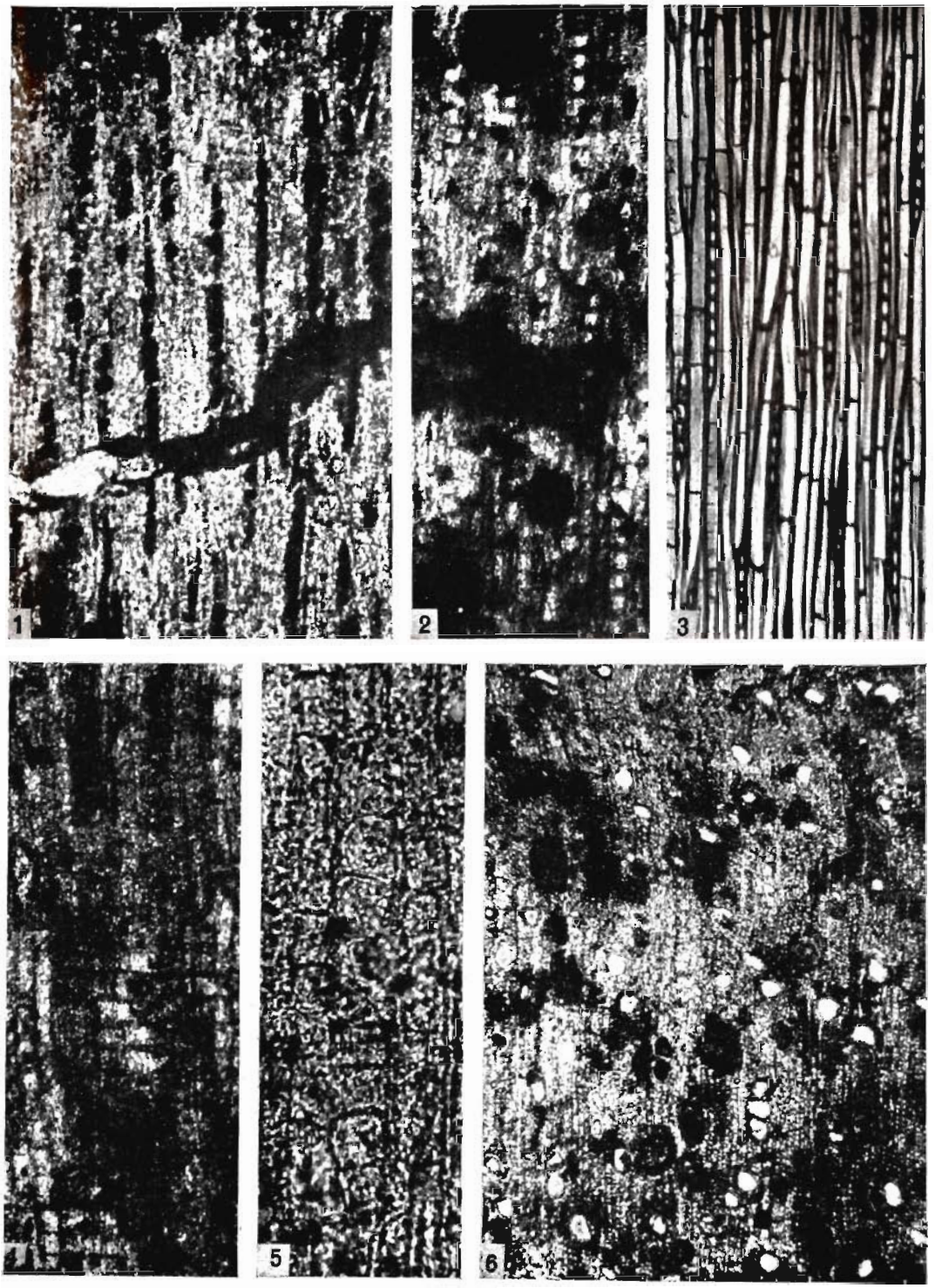


PLATE 26

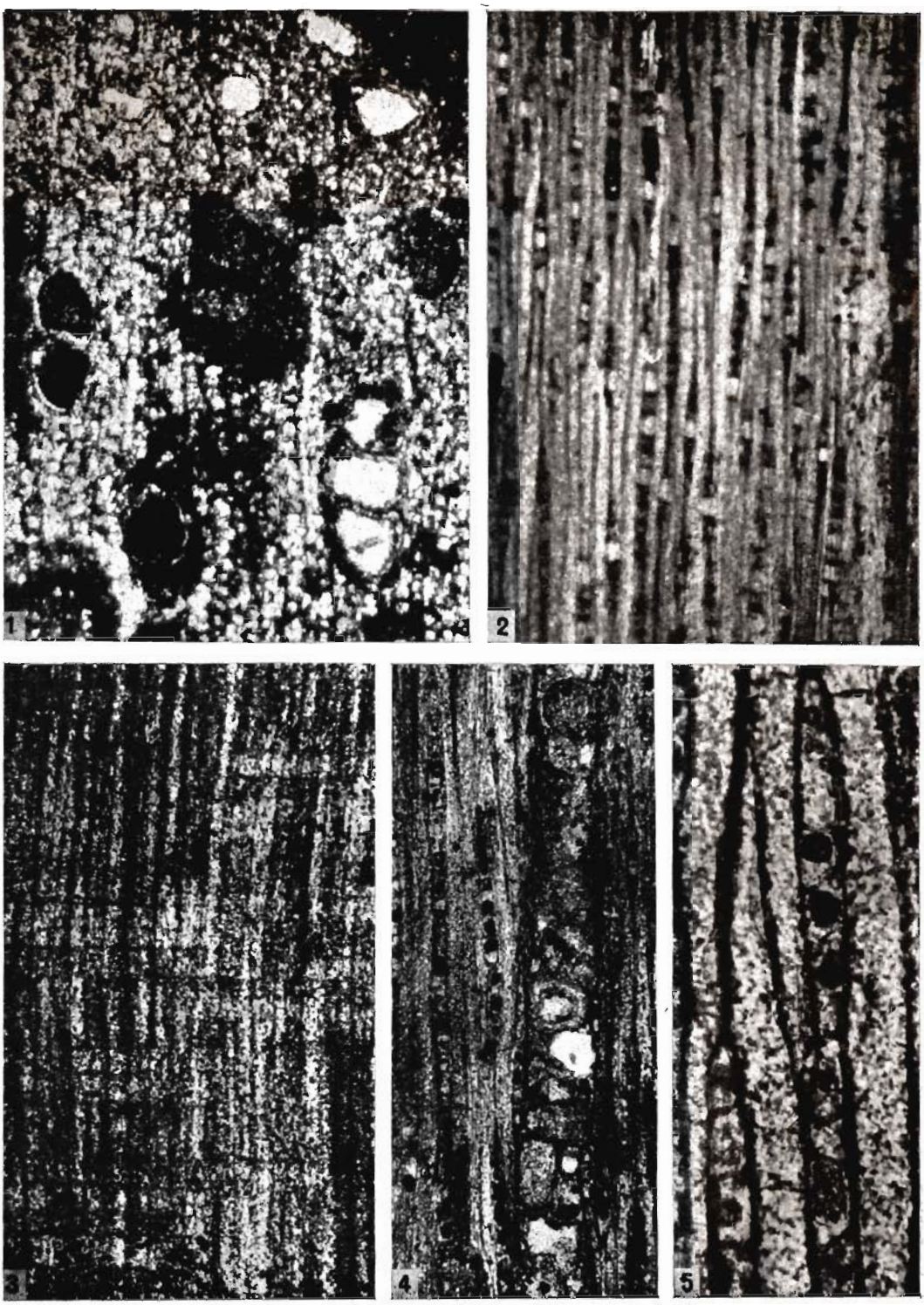


PLATE 27

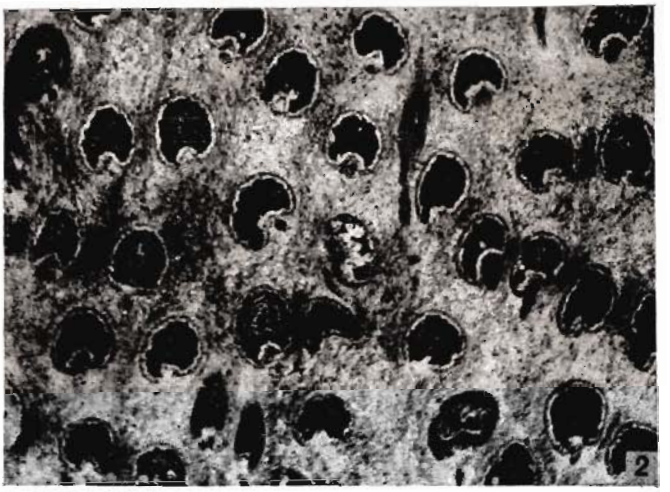


PLATE 28

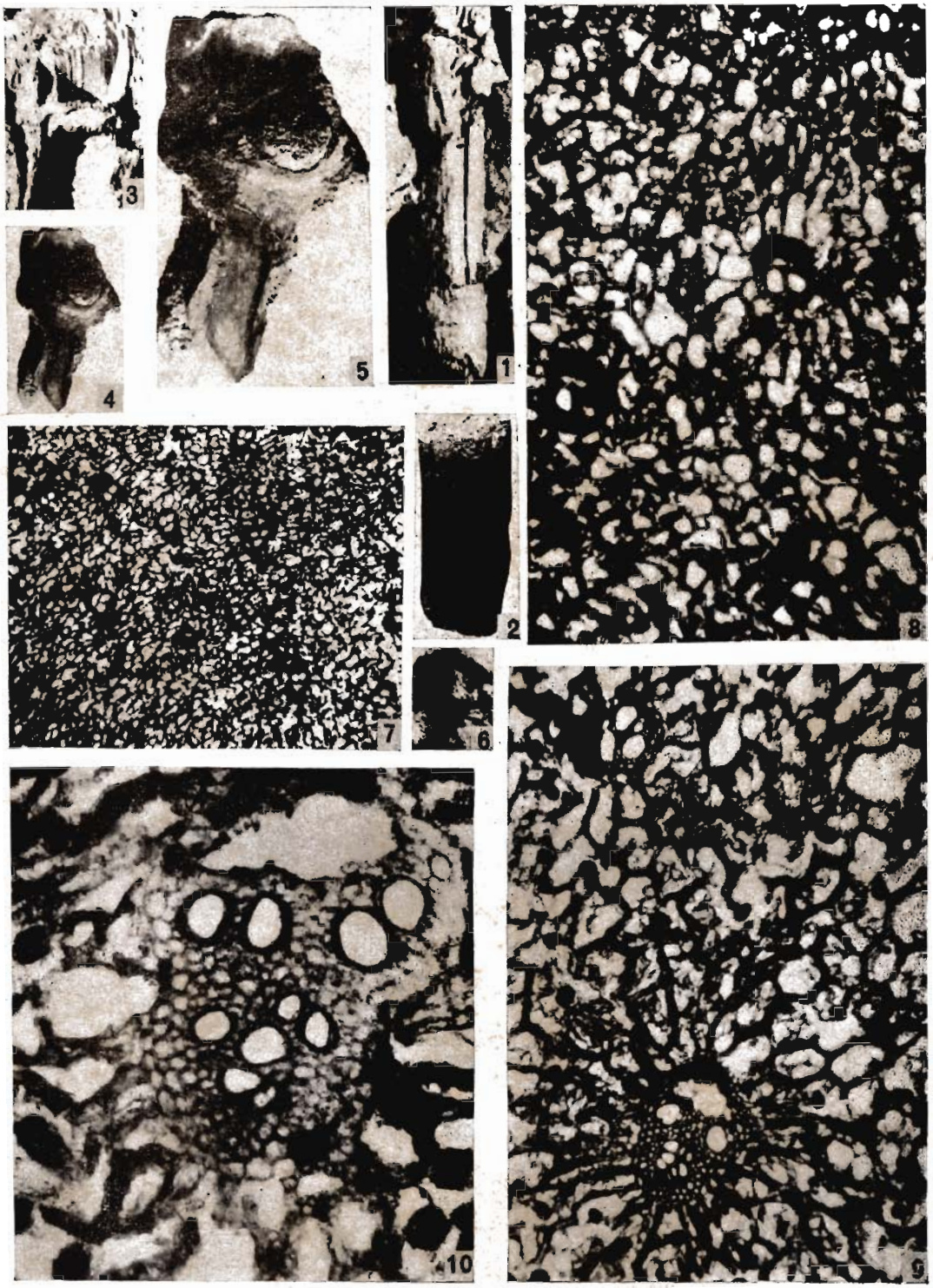


PLATE 29

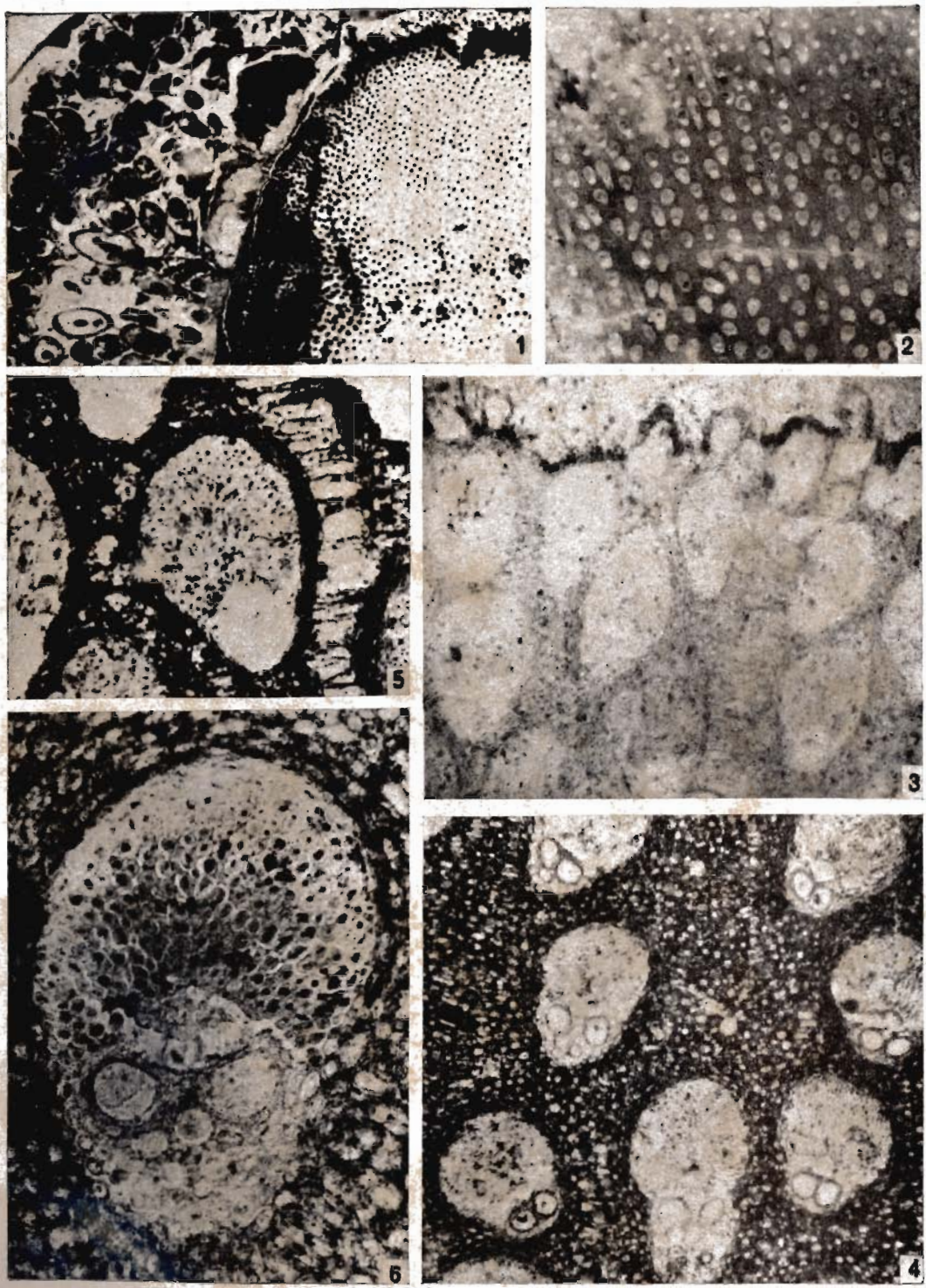


PLATE 30